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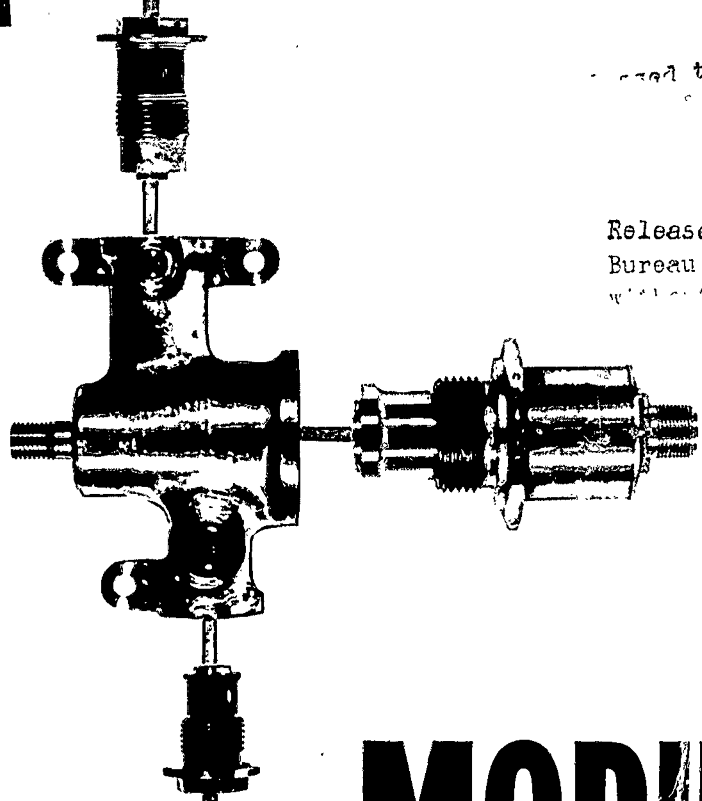


MODULAR HYDRAULICS

FINAL REPORT

BuWeps Contract 59-6019 C

PART II

CHANCE VOUGHT AERONAUTICS DIVISION

FOR ERRATA

AD 273 210

THE FOLLOWING PAGES ARE CHANGES

TO BASIC DOCUMENT

Addendum to AD-273 210

AD 273 210

273 210

MODULAR HYDRAULIC SYSTEM DEVELOPMENT
PROJECT HYDRATOY

ADDENDUM TO PART II
FINAL ENGINEERING REPORT
AER-E1R-13120
28 February 1962

Prepared Under Contract NOas 59-6019
Bureau of Naval Weapons Equipment Divis

Prepared by G. Gilder
Applied Systems Design

Approved by G. A. Starr
G. A. Starr
Chief, Applied Researc
and Development

ADDENDUM TO SECTION IV, CONCLUSIONS

At the time the final report was prepared six valves were still undergoing qualification tests. The six units are as follows:

1. Relief valve - 25 GPM - Benbow Manufacturing Company
2. Two way, two position selector valve - 25 GPM - Hydro Aire Company
3. Three way, two position selector valve - 25 GPM - Hydro Aire Company
4. Solenoid operated sequence valve - 12 GPM - Hydro Aire Company
5. Four way, three position selector valve - 12 GPM - Ronson Hydraulic Units Corporation
6. Priority valve - 4 GPM - Fluid Regulators Corporation

Each of these units had been plagued with development problems which delayed the start of qualification. Several major design changes were made in each valve. This, of course, required that new hardware be fabricated each time a design change was found necessary. The problems encountered were typical of those discussed in Section III. The costs incurred by the manufacturers of these units rose appreciably because of the prolonged development period.

Only item 5, the face mounted four way valve, successfully completed qualification and is recommended for the qualified parts list.

Item 1, the pilot operated relief valve, failed in the endurance test by hanging in the open position. The cause of failure appeared to be dimensional instability of valve body and slider; therefore, a second valve was fabricated adhering to the heat treating practices discussed in Section III. This unit was subjected to the entire series of qualification tests

only to fail during the last portion of vibration test. Once again galling had occurred. The valve had an extremely flat flow versus pressure drop curve. While the unit holds much promise, further study of the materials used is needed to overcome its tendency to gall.

Items 2, 3, and 4 were being qualified simultaneously (in the same set up), but each experienced failures. Solenoid failures were the major problem with these units. Development of these three units has been terminated at the request of the manufacturer.

Item 6, the priority valve, entered qualification but subsequently began to function erratically. Rework and further development did not yield a valve which met requirements of the procurement specification. One sliding member within the valve has a very thin wall which is subjected to unbalanced pressures. The resulting distortion is sufficient to bind the slider and mating parts. Development has been cancelled at the request of the manufacturer.

Hardware produced has now been forwarded to the Hydraulics Laboratory at the U.S. Naval Air Material Center.

VOUGHT AERONAUTICS
DALLAS 22, TEXAS
A DIVISION OF CHANCE VOUGHT CORPORATION

MODULAR HYDRAULIC SYSTEM DEVELOPMENT
PROJECT HYDRATOY

PART II
FINAL ENGINEERING REPORT
AER-E1R-13120
31 August 1961

Prepared Under Contract NOas 59-6019c
Bureau of Naval Weapons, Airborne Equipment Division

Prepared by G. Gilder
Applied Systems Design

Approved by G. A. Starr
G. A. Starr
Chief, Applied Research
and Development

ABSTRACT

This is the final report of a research and development program sponsored by the Airborne Equipment Division of the Bureau of Naval Weapons for the development of Modular Hydraulic components and concepts. The program is informally called "Project Hydratoy" and was initiated in December of 1958. The technical monitor for the program was Mr. B. L. Mettee of the Airborne Equipment Division.

In general terms, the program's basic objectives are to:

1. Package groups of individual components into one housing to save weight and space and to gain reliability.

2. Make the use of packages more attractive and to simplify installation and maintenance by providing a standard line of self-contained cartridge-like components for use in these packages.

3. Carry this integration one step further and investigate ways and means of physically integrating the complete hydraulic system into its supporting structure.

4. Develop the above concepts for a 450°F, 4,000 psi hydraulic system using corrosion-resistant materials and metallic seals.

This report is published in four separately bound parts:

Part I contains results of metallic seal and package development.

Part II presents results of modular component development and the specifications and standards for those components.

Part III contains results of development in the integrated system concept and design criteria for that concept.

Part IV is a report of materials and process development which occurred in conjunction with and as a result of development effort in metallic seals, packages, components, and system integration.

NOTICE

ACKNOWLEDGEMENTS

Chance Vought Corporation wishes to acknowledge its indebtedness to the many companies of the hydraulic equipment industry which participated in the development of the modular components. A large number of companies submitted design proposals which were useful in establishing the envelopes for the various units. Of the companies awarded development contracts, many experienced development problems which necessitated expenditures above those for which they were compensated. While the program was not profitable for some of these, the experience gained has helped to place these organizations in a position of leadership in the field of high temperature hydraulic equipment.

The following persons have contributed to the modular component development work reported herein:

G. K. Fling - Principal Investigator
J. H. Ballantoni
C. C. Collier
J. R. Moore

CONTENTS

Page

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

The modular hydraulic program was initiated for the purpose of improving aircraft hydraulic systems through the use of the packaged system concept. The potential improvements to be realized are: a reduction in space requirements; improved system reliability through reduction in leak points; improved system maintenance; reduction in system weight; and reduced logistical effort through standardization of components.

The objective of Phase II was to develop and qualify a series of modular hydraulic components for application in Type III, packaged systems. It was required that the components be capable of continuous operation in MLO-8200 fluid at 450°F with ambient temperature of 650°F. The development and qualification of the series of components was accomplished through the combined efforts of Chance Vought Corporation and a large segment of the hydraulic equipment industry. A total of twenty components have successfully completed qualification tests and are suitable for use in Type III systems with growth potential for Type IV systems.

I

DESIGN PHILOSOPHY

Previous hydraulic package designs had been for specific applications with no attempt to standardize the valves which, with a manifold, made up the package. The objective of this phase was to develop and qualify sample units of a selected list of hydraulic components which are used in most systems. Originally a high temperature capability of 400°F was selected for this program to agree with the temperature range arbitrarily established for the Type III system. However, when it became apparent that actual aircraft being developed by North American Aviation for the Air Force would require 450°F capability, it was decided that an increase to this value would result in more usable standards. This decision meant that the valves had to be designed around metallic seals rather than elastomeric seals and that MLO-8200 hydraulic fluid would be used instead of MLO-8515 fluid. The nominal system pressure was selected to be 4,000 psi. Burst pressure was taken as 10,000 psi at room temperature while proof pressure was taken as 6,000 psi at 450°F.

In order to coordinate the development work being done on the modular hydraulics program with the weapon systems being designed by both Air Force and Navy Contractors, an industry conference was held at Chance Vought on January 19th and 20th, 1959. In addition to the previously mentioned ground rules the following decisions were reached at the conference:

(1) Vibration tests will be required as a part of qualification of each component.

(2) Components must be capable of operation with the fluid temperature from -65 to + 450°F but should not be required to meet response requirements, pressure drop requirements, et cetera, below -20°F.

(3) The usual 168 hour soak at high temperature is not required as a part of qualification since metallic seals are used in place of elastomeric seals.

(4) The components should be a stepped configuration with the metallic seals located on these steps. The step design makes it impossible to install a valve backward in a manifold.

(5) Only one unit of each type and size need undergo qualification. Maximum and minimum tolerance units are usually qualified to verify the design under conditions of varying "O" ring squeeze. This, it was felt, is not necessary when metallic seals are used. A mathematical analysis of clearances is required to show that seizure of mating parts will not occur when the parts are made to the extremes of tolerance permitted by detail drawings.

The components selected for development are listed in Table 1. Many of these units were developed in several sizes to handle different flow rates (0 to 4 GPM, 4 to 12 GPM, or 12 to 25 GPM) or different pressure ranges. Each unit was designed to incorporate a different size thread or some other device to prevent one unit from inadvertently being installed in the cavity intended for a different type of component. This feature should improve system reliability by making it impossible for

TABLE 1

COMPONENTS SELECTED FOR DEVELOPMENT

Components	Sizes	Number of Vendor Contracts	Total Units
(1) thermal relief valve	3	3	9
(2) pressure relief valve	2	2	6
(3) check valve	3	3	9
(4) shuttle valve	3	3	9
(5) one way restrictor	1	1	3
(6) two way restrictor	1	1	3
(7) filter	3	3	9
(8) priority valve	3	3	9
(9) pressure operated shut-off valve	3	3	9
(10) pressure switch	1	1	3
(11) solenoid operated sequence valve	2	2	6
(12) solenoid operated shut-off valve	1	2	6
(13) solenoid operated 3 way 2 position valve	2	3	9
(14) solenoid operated 4 way 3 position valve	3	3	9
Totals	31	33	99

maintenance personnel to install the wrong valve or to install a given valve backwards. Each cartridge valve has been designed as a self-contained component which may be removed from one package and installed in another without disassembly, readjustment of setting, or impairment of function. Many packaged systems utilize an approach wherein poppets, springs and other items making up a valve are assembled directly into the package instead of being self-contained. This approach is not compatible with the goals of standardization, ease of system maintenance, reliability, and low overall cost which are possible through the packaged system concept.

Components are generally qualified in exceptionally clean systems which are not typical of the systems in operational aircraft. It is desirable that components be qualified in a system which is as much as possible like the system in which they will be used. To assure that the modular valves would be tolerant of contamination, a controlled amount of contaminant was added to the qualification test systems.

A cavity was established for each component to assure proper fit of the module in the package and proper squeeze on the metallic seals. These cavities may be seen in the suggested MS pages enclosed in the appendix to this report. To eliminate the possibility of installing the wrong size or type component, each cavity differs for all sizes and types of component. A thin-walled test housing was designed for each component and forwarded to the vendors as suggested test housings for qualification tests. The thin-walled test housing simulates the type of manifold which is used in flying hydraulic systems.

II

DEVELOPMENT PROCEDURE

Immediately following the conference of Naval, Air Force, and airframe manufacturer representatives a symposium was held with 150 representatives of the hydraulic equipment industry to present a briefing on Project Hydratoy, to exchange ideas, and to gather opinions. At this symposium a minimum requirement specification was distributed to all interested vendors and non-competitive, preliminary proposals were invited to aid in establishment of envelopes. Upon receipt of these preliminary proposals Chance Vought Corporation began an evaluation with a view toward determining the minimum reasonable envelope for the most feasible designs proposed. A procurement specification and an envelope control drawing were then prepared for each component. These were sent to each vendor who submitted a preliminary proposal. Upon receipt of the final proposals the bids were reviewed, designs were reviewed, and a selection of vendors was made jointly by the Bureau of Naval Weapons and Chance Vought Corporation. Table 2 lists the manufacturers who submitted a proposal on each specific valve. Contract awards were then made for the development and qualification of the components. Each contract specified that three components of each type were to be manufactured. One became the qualification unit while the other two were subjected to acceptance tests by Chance Vought. The knowledge gained throughout the development and qualification programs was fed back for incorporation into the MIL type specification and MS type drawing which has been prepared for each component. The complete set of specifications and suggested MS standards may be seen in the appendix to this report.

In establishing the envelope for these valves, the preliminary proposals received were placed on charts to facilitate comparison. These were then reviewed to determine those designs which best met the requirements of the applicable procurement specification. They were then narrowed down to a single design or usually a composite design around which an envelope could be established. The design approach selected was modified to accept metallic seals of the sizes listed in specification CVC 2464 (see appendix, Part 1 of this report). The design was further modified to affect miniaturization. Consideration was given to the flow area requirements around all valve ports which would enable the valve to pass rated flow without exceeding the allowable pressure loss. A nominal fluid velocity of 25 feet per second was used as a guide in determining the size of the various valves. It was originally planned that three sizes of valve would be developed in the pressure relief valve, solenoid operated shut-off valve, solenoid operated sequence valve, and the solenoid operated 3-way, 2-position valve. Each size was intended to cover one of the flow rates 0 to 4 GPM, 4 to 12 GPM or 12 to 25 GPM. Design layouts were made for each flow rate; however, the increment of increase in dimensions was so small between one class and the next that three separate valve standards are not warranted. In the case of the solenoid operated valves the solenoid is the same size regardless of the flow capacity of the main stage. It can be seen that the solenoid and the pilot stage, which together comprise the bulk of a valve, are unaffected by flow rate. Only the size of the main stage increases for higher flow rates.

TABLE 2

LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT

CHECK VALVE	RESTRICTOR
Accessory Products Company	Accessory Products Company
Air Products Company	Air Products Company
Altair, Inc.	Altair, Inc.
Benbow Manufacturing Company	Benbow Manufacturing Company
Com-Air Products	Com-Air Products
Conair, Inc.	Conair, Inc.
Crescent-Sargent Corporation	De Coto Brothers
Crissair	Gar Precision Parts
De Coto Brothers	Hydro-Aire, Inc.
Fluid Regulators Corporation	Integral Corporation
Gar Precision Parts	Langley Corporation
Hydro-Aire, Inc.	Lear, Inc.
Integral Corporation	M.C. Manufacturing Company
James, Pond and Clark, Inc.	Pantex Manufacturing Company
Langley Corporation	Pneudraulics, Inc.
Lear, Inc.	Republic Manufacturing Company
M.C. Manufacturing Company	Randall Engineering Corporation
Pantex Manufacturing Company	Ronson Hydraulic Units
Pneudraulics, Inc.	Vinson Manufacturing Company
Republic Manufacturing Company	The Weatherhead Company
Randall Engineering Corporation	

TABLE 2 LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT (Continued)

CHECK VALVE

Ronson Hydraulic Units

Vinson Manufacturing Company

The Weatherhead Company

THERMAL RELIEF

Altair, Inc.

Benbow Manufacturing Company

Bendix-Pacific Division

Besler Corporation

Com-Air Products

Fluid Regulators Corporation

Gar Precision Parts

Hydra-Power Corporation

Hydraulic Research

M. C. Manufacturing Company

Pantex Manufacturing Company

Parker Aircraft Company

Pneudraulics, Inc.

Republic Manufacturing Company

Randall Engineering Corporation

Sargent Engineering Corporation

Tavco, Ltd.

Vinson Manufacturing Company

SHUTTLE

Altair, Inc.

Benbow Manufacturing Company

Com-Air Products

De Coto Brothers

Hydro-Power Corporation

Langley Corporation

M.C. Manufacturing Company

Parker Aircraft Company

Randall Engineering Corporation

Ronson Hydraulic Units

Sargent Engineering Corporation

Vinson Manufacturing Company

The Weatherhead Company

PRIORITY VALVE

Adel Precision Products

Bendix-Pacific Division

Com-Air Products

Fluid Regulators Corporation

TABLE 2 LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT (Continued)

THERMAL RELIEF

The Weatherhead Company

SEQUENCE VALVE

Altair, Inc.

Bendix-Pacific Division

Com-Air Products

Hydro-Aire

Ronson Hydraulic Units

RELIEF VALVE

Adel Precision Products

Altair, Inc.

Benbow Manufacturing Corporation

Bendix-Pacific Division

Carleton Aviation

Com-Air Products

Fluid Regulators Corporation

M. C. Manufacturing Company

Pneudraulics, Inc.

Republic Manufacturing Corporation

Sargent Engineering Corporation

Tavco, Ltd.

Vinson Manufacturing Company

The Weatherhead Company

Whittaker Controls

FOUR-WAY VALVE

Altair, Inc.

PRIORITY VALVE

Hydra-Power Corporation

Hydro-Aire

Parker Aircraft Company

Sargent Engineering Corporation

Vinson Manufacturing Company

PRESSURE SHUT-OFF

Adel Precision Products

Altair, Inc.

Bendix-Pacific Division

Com-Air Products

Fluid Regulators Corporation

Hydra-Power Corporation

Hydro-Aire, Inc.

Republic Manufacturing Company

Randall Engineering Corporation

Ronson Hydraulic Units

Sargent Engineering Corporation

Tavco, Ltd.

Vinson Manufacturing Company

Waldorf Instrument Company

The Weatherhead Company

PRESSURE SWITCH

Aircraft Controls Company

TABLE 2 LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT (Continued)

FOUR-WAY VALVE

Bendix-Pacific Division

Hydro-Aire

Ronson Hydraulic Units

Sargent Engineering Corporation

Whittaker Controls

Weston Hydraulics, Ltd.

PRESSURE SWITCH

Benbow Manufacturing Corporation

Century Electronics

Cook Electric Company

Randall Engineering Corporation

Rochester Gage Company

THREE-WAY SELECTOR VALVE

Adel Precision Products

Altair, Inc.

Bendix-Pacific Division

Hydra-Power Corporation

Hydro-Aire, Inc.

Moog Servocontrols, Inc.

Parker Aircraft, Inc.

Randall Engineering Corporation

Ronson Hydraulic Units

Sargent Engineering Corporation

Vinson Manufacturing Company

Whittaker Controls

TWO-WAY SELECTOR VALVE

Adel Precision Products

Altair, Inc.

Bendix-Pacific Division

Com-Air Products

Hydra-Power Corporation

Hydro-Aire, Inc.

Marotta Valve Corporation

Parker Aircraft Corporation

Randall Engineering Corporation

Ronson Hydraulic Units Corporation

Sargent Engineering Corporation

Vinson Manufacturing Company

FILTER ASSEMBLY

Aircraft Porous Media

Bendix - Filter Division

Permanent Filter Corporation

Development contracts were awarded to component suppliers as noted in Table 3.

In the development program for each component listed above, the manufacturer was required to submit, for approval, a qualification test procedure and a test housing design. The development program was monitored through qualification and approval of the qualification test report.

TABLE 3

LIST OF MANUFACTURERS AWARDED DEVELOPMENT CONTRACTS

Check Valve	4 GPM	Crescent Sargent Corporation 5543 E. Admiral Place Tulsa, Oklahoma
(Qualification performed by Aerotest Laboratories)		
Check Valve	12 GPM	Gar Precision Parts, Inc. 36 Ludlow Street Stanord, Connecticut
(Qualification performed by Aerotest Laboratories)		
Check Valve	25 GPM	Republic Manufacturing Company 15655 Brookpark Road Cleveland 11, Ohio
(Qualification performed by Aircraft Equipment Testing Company)		
One way restrictor	0 to 4 GPM	Ronson Hydraulic Units Corporation 1313 Lincoln Avenue Pasadena, California
Two way restrictor	0 to 12 GPM	Ronson Hydraulic Units Corporation
Thermal relief valve	2100 to 3100 psi	Bendix-Pacific Division 11600 Sherman Way North Hollywood, California
Thermal relief valve	3100 to 4100 psi	Fluid Regulators Corporation 313 Gillette Street Painesville, Ohio
(Qualification performed by Wyle Parameters Laboratories)		
Thermal relief valve	4100 to 5100 psi	Altair, Incorporated 50 St. McQuesten Pkwy. Mt. Vernon, New York
(Qualification performed by Aerotest Laboratories)		
Shuttle Valve	4 GPM	Consolidated Controls Corporation 750 S. Isis Avenue Englewood, California
(Qualification performed by Garwood Laboratories)		
Shuttle Valve	12 GPM	Ronson Hydraulic Units Corporation
Shuttle Valve	25 GPM	Langley Corporation 310 Euclid Avenue San Diego, California
(Qualification performed by Garwood Laboratories)		

TABLE 3 (Continued)

Pressure Switch		Rochester Manufacturing Co. Rochester, New York
Three way selector valve	4 GPM	Sargent Engineering Corporation 2533 East 56th Street Huntington Park, California
Three way selector valve	25 GPM	Hydro-Aire, Inc. 3000 Winona Avenue Burbank, California
(Qualification performed by Ronson Hydraulic Units Corp.)		
Three way selector valve	25 GPM	Whittaker Controls 915 North Citrus Ave. Los Angeles 38, California
Priority valve	4 GPM	Fluid Regulators Corporation 313 Gillette Street Painesville, Ohio
(Qualification performed by Wyle Parameters)		
Priority valve	12 GPM	Hydra Power Corporation Pine Court New Rochelle, New York
(Qualification performed by Aerotest Laboratories)		
Priority valve	25 GPM	Sargent Engineering Corporation
Pressure operated shut-off valve (Not qualified)	4 GPM	The Weatherhead Company 300 E. 131st Street Cleveland, Ohio
Pressure operated shut-off valve (Not qualified)	12 GPM	Hydra Power Corporation
Pressure operated shut-off valve (Not qualified)	25 GPM	Republic Manufacturing Corporation
Relief valve	4 GPM	M. C. Manufacturing Company P. O. Box 126 Lake Orion, Michigan
(Qualification performed by Aircraft Equipment Testing Company)		

TABLE 3 (Continued)

Relief valve	25 GPM	Benbow Manufacturing Company 11920 Jefferson Boulevard Culver City, California
(Qualification performed by Chance Vought Corporation)		
Solenoid operated shut-off valve	25 GPM	Bendix-Pacific Division
Solenoid operated shut-off valve	25 GPM	Hydro-Aire
(Qualification performed by Ronson Hydraulic Units Corp.)		
Solenoid operated sequence valve	12 GPM	Hydro-Aire
(Qualification performed by Ronson Hydraulic Units Corp.)		
Solenoid operated sequence valve	25 GPM	Ronson Hydraulic Units Corporation
4 way, 3 position selector valve (cartridge type)	4 GPM	Whittaker Controls
4 way, 3 position selector valve (face mounted type)	12 GPM	Ronson Hydraulic Units Corporation
4 way, 3 position selector valve (cartridge type)	25 GPM	Bendix-Pacific Division
Filter	4 GPM	Bendix-Filter Division 434 West 12 Mile Road Madison Heights, Michigan
Filter	12 GPM	Aircraft Porous Media Glen Cove, New York
Filter	25 GPM	Aircraft Porous Media

III

DEVELOPMENT PROBLEMS

Numerous problems have been experienced by the manufacturers having development contracts. Problems, however, are to be expected when an advance in the state of the art is attempted to produce components which operate at higher temperatures and pressures and which are produced in new configurations.

The problem which has occurred most frequently is that of seal leakage. Many of the component manufacturers had little or no experience with metallic seals prior to the Project Hydratoy program. Surface finish and amount of squeeze must be controlled much more closely for metallic seals than for elastomeric seals. It was necessary to develop an awareness of minute details which are essential to the satisfactory performance of a metallic seal. The force required to compress the seal is large; consequently, components were often assembled by torquing parts together until the torque was felt to be sufficient. This method of assembly is not dependable, for the seals were frequently not compressed enough to affect a leakproof joint. Each assembly is designed to impart the proper squeeze to the seal when the mating parts bottom out on each other. Therefore, the recommended assembly procedure is as follows. The parts should be assembled without any seals until they bottom out on each other. An index mark should be placed on the two parts to indicate the position where bottoming occurs. The part should then be disassembled and reassembled using the proper seals. Sufficient torque must be applied to align the scribe marks. In

some of the larger components where multiple seals are compressed on installation, the torque may become excessive and cause thread galling. This can be prevented by presetting each seal individually. Presetting a seal consists of installing only one seal at a time and bottoming out the parts so that the seal takes a permanent set. A thread lubricant is also desirable. With proper attention to the details of manufacturing and assembling parts, excellent results can be expected from the Hi Ceal.

Cartridge configuration - A second problem has occurred on several slide type valves which does not exist in a conventional or non-cartridge valve. The cartidge valve allows flow and pressure around the outside of the valve body. As shown in Figure 1 the slider can be so positioned that the pressure on the outside of the body is not balanced by an equal pressure inside the body. The valve body (part number 2) is thus made to contract because of this differential pressure and seize the slider (part number 1). In the conventional valve pressure is always contained within the valve body so that the effect of pressure is to increase the clearance between body and slider. This type of piston seizure occurred on all three sizes of the pressure operated shut off valves which were developed. The three sizes were each developed by a different manufacturer although the designs were somewhat similar. Each unit could be made to open and close within a very narrow range of actuation pressures so long as the inlet pressurization was low. However, as the inlet pressure was increased to 4,000 psi the actuation pressure required to open the valve became larger while the actuation pressure required to close the valve was reduced. At times certain ones of the valves tested at Chance Vought remained fully open with complete

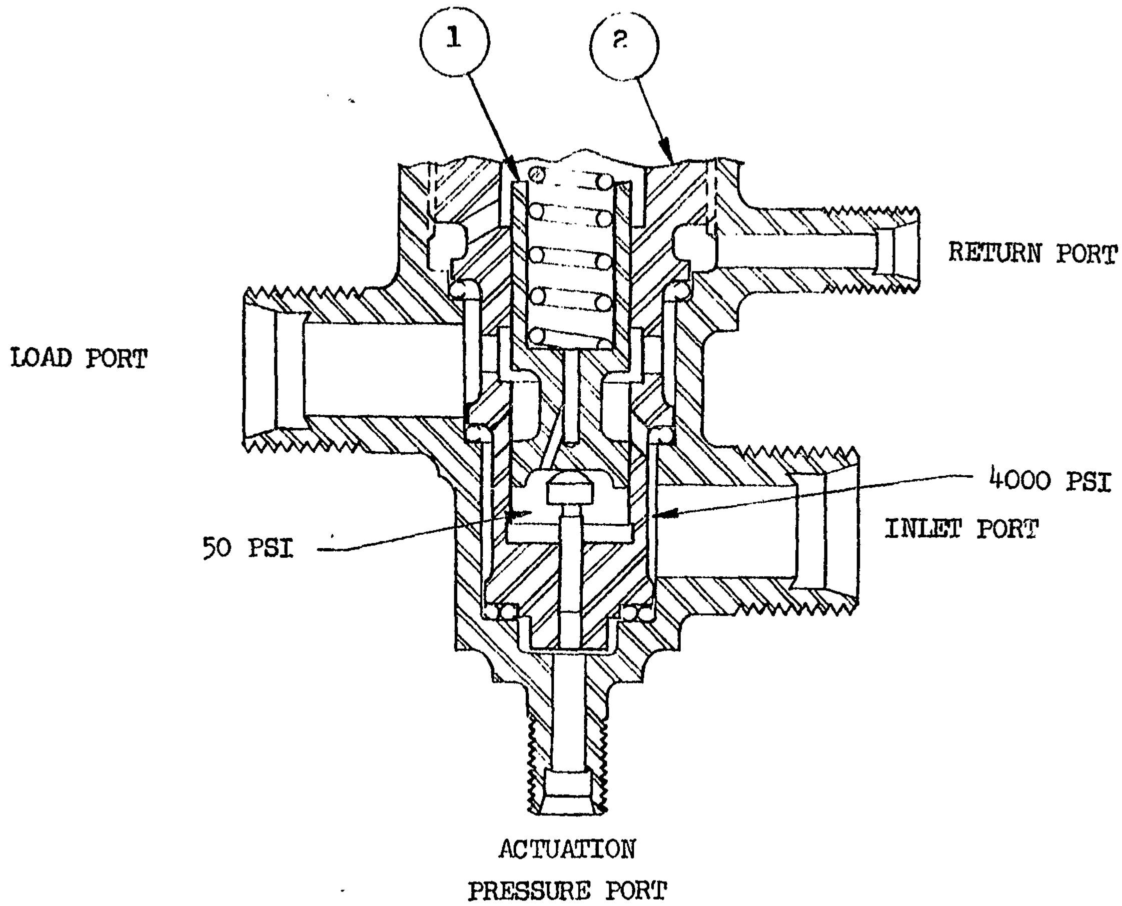


FIGURE 1

TYPICAL PRESSURE OPERATED SHUT-OFF VALVE INSTALLED IN TEST MANIFOLD

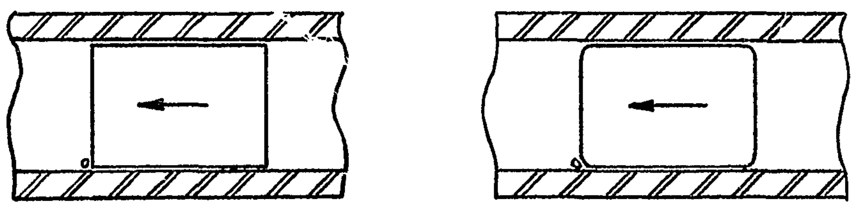
removal of the actuation pressure until the inlet port pressurization was reduced. Late in the program it became apparent that the shut off valves could not be made to function satisfactorily without a complete redesign. It was calculated that contraction of the valve body diameter due to external pressure was of a magnitude of 0.0002 inch. None of the three valve designs were successful in passing qualification tests. Both the suggested MIL specification and MS standard page for the pressure operated shut off valve are enclosed in the appendix. It is possible that relocation of the seals from the positions shown might made a redesign easier to accomplish.

Lapped fits - There is much to be said on the subject of lapped fits. Since there is no really good dynamic seal suitable for the environment specified, lapped fits are utilized extensively within these valves to eliminate dynamic seals. Some of the many facets of lapped fits which have been of concern in the modular program will be discussed.

Hydraulic lock - Several selector valves experienced hydraulic lock causing the slider to hang in one position or another during development tests. Hydraulic lock is a relatively high static friction force which is produced by pressure acting on one side of the slider - forcing the slider against one wall of the valve body. The force, normal to the axis of the slider, may be reduced by the addition of labyrinth grooves in the slider. The addition of labyrinth grooves is quite effective in overcoming hydraulic lock. A surprisingly large number of valve manufacturers design valve spools without grooves in the lands. The grooves

are added only after hydraulic lock has occurred on a given design. This is probably because the research work which has been performed relative to hydraulic lock is not widely known. Some experimental work has been done to determine the variation of breakout force with the number of the grooves.[1] A quantitative theory of the pressure distribution and the resulting land force for various land configurations has also been developed.[2] Some designers add grooves in an attempt to reduce leakage rate - the theory being that grooves help to keep the spool concentric within the valve body. Other designers dispute this, and there seems to be little evidence to support the theory that the labyrinth grooves reduce leakage rate of an incompressible fluid.

Lap damage from contamination - Galling and seizure of lap assemblies sometimes occur because of contaminant being wedged into the clearance between spool and valve body. The land should intersect the groove of a spool with a sharp corner to reduce the tendency of galling from this cause.



Particles larger than about 5 Microns unable to get into clearance gap.

With radius on spool, larger particles can wedge into clearance gap.

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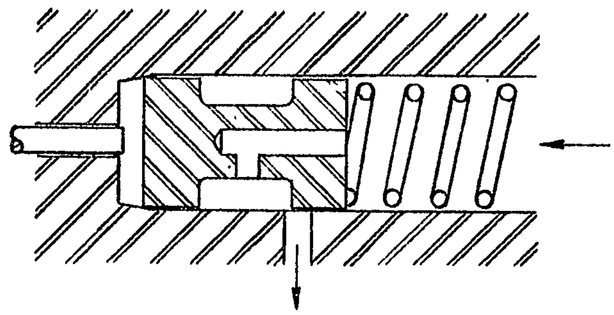
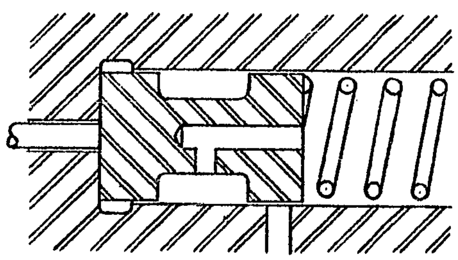
[1] D. C. Sweeney, "Preliminary Investigation of Hydraulic Lock," Engineering, Vol. 172 (1951), pp 513-516 and 580-582.

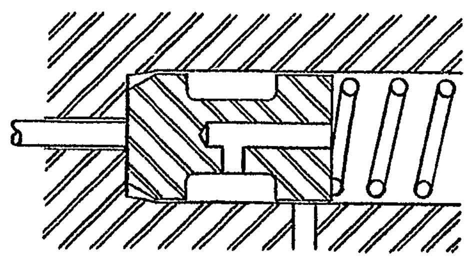
[2] J. F. Blackburn, G. Reethof and J. L. Shearer, Fluid Power Control, (New York: Wiley and Technology Press of M.I.T., 1960), pp 279-289.

Blind laps - Manufacturing problems arose on several valves in which the female part was designed as a blind lap. This was caused by the designer failing to allow sufficient room for the lead taper on the lapping tool. Excessive leakage occured because the valve spool could not reach the intended shut-off position.



Blind laps presented no problem where a relief was provided on either the spool or the bore as shown below.





Leakage rate - Leakage rates are predicted through calculations in the detail design of any valve. The equation used to calculate leakage rate from an annular flow path shows that the leakage varies inversely as the absolute viscosity of the fluid.

$$Q = \frac{\pi D b^3 \left(1 + 1.5 \left(\frac{E}{b}\right)^3\right) (Pu - Pd)}{12 \mu L}$$ [3]

where μ = fluid viscosity, lb sec/sq in
Q = volume flow rate, cu in/sec.
D = diameter of passage, inch
b = passage height, inch
Pu = upstream pressure, lb/sq. in
Pd = downstream pressure, lb/sq in
L = passage length (in direction of flow), inch
E = eccentricity of spool within sleeve, inch

The kinematic viscosity of Oronite 8200 fluid is approximately 35 centistokes at 90°F and 3 centistokes at 450°F while the density is approximately 0.925 gms/cc at 90°F and 0.765 gms/cc at 450°F.[4] Using these values, the absolute viscosity may be determined to be 34.8×10^{-5} lb. sec/sq in at 90°F and 2.47×10^{-5} lb. sec/sq in at 450°F. The viscosity change corresponding to this temperature change is in the ratio 14 to 1. The equation shown above then indicates that leakage rate will be approximately 14 times as great at 450°F as would be experienced at 90°F in the same parts. In practice the leakage rate has not changed by an amount approaching the calculated change. In tests of lapped valves, the leakage rate at 450° has been from 1 to 2.5 times the values recorded at 90°F. Certainly pressure as high as 4,000 psi alters the viscosity, but no data is available. The values of viscosity quoted above are for atmospheric pressure. Also the length of the waiting period before measurement is begun greatly affects the rate which will be measured. Even in well filtered systems, silting will

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[3] Ibid., p. 58

[4] N.W. Furby, R. L. Peeler and R. I. Stirton, "Oronite High-Temperature Hydraulic Fluids 8200 and 8515," A.S.M.E. paper No. 56--AV-22, (New York:A.S.M.E., 1956), Figs 3,4.

occur to a degree sufficient to lower the leakage rate. The amount of contaminant in the system will thus affect the leakage rate measured in acceptance testing a lapped hydraulic valve.

Part distortion - The four way, three position selector valve has been developed in two configurations: (1) face mounted and, (2) cartridge. The main stage of each valve type is a lap assembly made up of a slider and the valve body. Very small deflections in the valve body are sufficient to cause seizure of the slider. Therefore, the face mounted valve must be mounted onto a manifold having a relatively flat face. In the development of the cartridge-type four way valve the radial, wedge seals introduced sufficient body distortion to create a sticking slider. It was concluded that the concept of a low leakage valve (i.e. 4cc/min) is not compatible with the tolerances which are reasonable for the wedge seals. The clearance between slider and valve body was ultimately increased until sticking of the slider no longer occurred. The internal leakage rate allowed was then increased proportionally. Measurements of one valve body showed that the wedge seals were forcing the body to go out of round by only 0.00009 inch, yet this was sufficient to cause seizure of the spool before the clearance was increased.

Wear of lap assemblies - Certain combinations of materials and surface treatments have been found to be successful in the slider and body making up a lap assembly. Some of the combinations which have demonstrated good wear resistance in qualification tests are listed below.

Body Material	Plating	Slider Material	Surface Treatment
17-4PH	None	17-4PH	Nitrided
17-4PH	None	17-4PH	Tungsten carbide
416	None	440C	Chrome
440C	None	440C	Chrome
440C	None	440C	Tufftride
440C	None	440C	None

Some attempts were made to use an unplated stainless steel against a stainless steel which was neither plated nor case hardened, and in several cases this was successful; however, this is not recommended for lap assemblies which are to operate in a fluid having relatively poor lubricity. Experience with bare lap assemblies varied from failures as disasterous as galled parts to only a more pronounced tendency toward hydraulic lock of the mating parts. Side loads, created by imperfect parts, flow forces, or the presence of contaminant, will promote failures of these types. Unplated assemblied have been very satisfactory for the type of valves wherein the clearance is 0.001 to 0.002 inch.

Dimensional stabilization - Three valves are known to have malfunctioned because of dimensional changes in the finished parts, and it is suspected that this was the cause of other failures. An adequate stabilization procedure should be contained in each valve manufacturer's heat treatment specification, inasmuch as the provisions of specification MIL-H-6875 are not sufficient for a lap assembly. Each of the valves in which this problem was evident had one or both parts making up the lap assembly made from 440C. The Metals Handbook, in discussing martensitic stainless steels, says "The higher-carbon martensitic grades such as 440C are likely to retain large amounts of untransformed austenite in the as quenched structure, frequently as much as 30% by volume. Stress

relieving at 300°F has little effect, since higher temperatures are required to achieve transformation. Delayed transformation may occur as a result of temperature fluxuations in service, thus resulting in embrittlement and serious dimensional changes. A portion of this retained austenite may be transformed by subzero cooling to about -100°F immediately after quenching. If some decrease in hardness can be tolerated, the steel should be stress relieved at a higher-than-normal temperature, preferably near 700°F. Two complete cycles of stress relieving are advisable, regardless of the temperature used. In combination with the higher stress-relieving temperature, the subzero treatment is less useful, although both treatments are recommended for maximum stability. In general, the high-carbon grades should be tempered at a temperature at least as high as that to which they will be subjected in service."[5] This situation is discussed further in Part IV of this report. It should be noted that a number of the valve manufacturers participating in the program subject their parts to three complete stabilization cycles. The recommended manufacturing sequence for unplated parts made of 440C is: (1) Machine parts to within about 0.002 inch of finish dimension; (2) Heat treat (harden, quench, three heat cycles from cold stabilization temperature to tempering temperature); (3) Finish grind; (4) Bake 4 hours and; (5) Finish lap.

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[5] American Society for Metals, Metals Handbook, ed. Taylor Lyman (8th ed; Novelty, Ohio: American Society for Metals, 1960), Vol I, p 419.

Di-electric breakdown - The manufacture of acceptable solenoids has been a sizeable problem for two of the five firms holding contracts for solenoid operated selector valves. These solenoids are required to operate in an ambient temperature of 650°F. Each of the five companies selected Ceramitemp wire after a survey of the available wires for this environment. The Ceramitemp wire (made by Hi-Temp Wires, Inc.) will withstand continuous operation at 650°F; however, the ceramic-type insulation is brittle and tends to flake off if care is not exercised in the winding and subsequent handling of the solenoid. Some of the solenoids are terminated with the Ceramitemp wire brazed directly to the connector while others utilize a lead wire to join the solenoid and connector. One type of lead wire is teflon insulated with a silicon - fiberglass cover over the teflon. Di-electric breakdown has occurred on numerous solenoids used by two of the five firms while the others have had little or no trouble of this nature. One of the manufacturers experiencing repeated di-electric failures has attributed the failures to carelessness in handling the solenoids.

Effect of temperature on pressure setting - Operation of certain components over a wide temperature range will cause a slight change in their operating characteristics. Spring-loaded valves such as relief valves will display a slightly lower cracking pressure at 450°F than at 95°F. The coefficient of elasticity of Inconel X and 17-7 PH stainless steel from which the springs are made decreases as the temperature is increased over this range. In the pressure switch a bourdon tube displays the same characteristic. The pressure at which the electrical contacts open is approximately 50 psi lower at 450°F than at 95°F.

If the system demands that a valve open at a constant pressure over a wide temperature range, some sort of a compensator may be included in the valve. This usually consists of an aluminum part or other material which has a higher coefficient of thermal expansion than the adjacent steel parts and which is incorporated in such a way that the spring is compressed further at high temperature. Usually the system does not require that the valve open within so narrow a limit as to warrant compensators.

Valve instability - Instability has been a problem to a varying degree in the development of thermal relief valves, pressure relief valves, and priority valves. The rated flow to be handled by the thermal relief valve has been increased to 0.1 GPM as compared with 15 cc/min required of the valves qualified under specification MIL-V-5527A. This increased flow requirement created instability problems which had not existed in earlier designs. Some experimental work was necessary in order to determine the amount of damping required to overcome the problem. It is interesting to note that only one manufacturer, of the many submitting proposals for the thermal relief valve, foresaw an instability problem and included a spring-mass-damper analysis as part of the preliminary design. This manufacturer was not awarded a development contract because of objections in the design of the pressure setting adjustment. The background for such an analysis may be found in any elementrary text on mechanical vibrations. Such an analysis could be applied to any direct operating relief valve so that the valve viscous damper is designed to provide a damping factor ratio C/C_c between 0.5 and 1.0, where

C_c, critical damping factor, $2\sqrt{mK}$

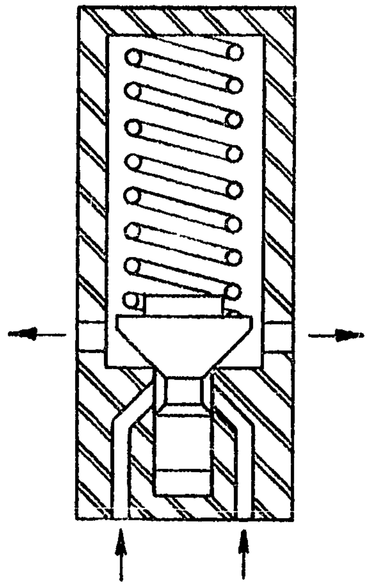
m, mass of poppet and damping piston

k, spring rate of spring

The pressure relief valves were of two types: (1) direct operating and, (2) pilot operated. These two valve types are schematically represented in Figure 2. Stability was achieved in the direct operated valve through the use of a damping piston. The clearance between the damping piston and the damping chamber was initially made as small as practical to produce a valve which was stable but sluggish. The clearance was then increased in small increments until a satisfactory compromise between response and stability was obtained. The pilot operated valve presented another set of problems. The pilot stage by itself functions just like a direct operating relief valve and is subject to instability if too high a flow rate is passed through the pilot stage. This can be overcome by restricting the amount of flow to the pilot stage. However, the location of the restriction within the main stage slider was found to be very critical. If located in a region of turbulent flow the valve will remain unstable. Therefore, the main slider was modified so that a projection containing the orifice extends into the less turbulent flow stream.

Two of the three priority valves tended to be unstable. One unit was very similar to the pilot operated relief valve discussed above. It was made stable by the addition of a flow limiter to the pilot stage.

DIRECT OPERATING RELIEF VALVE
WITH DAMPING PISTON



PILOT OPERATED RELIEF VALVE

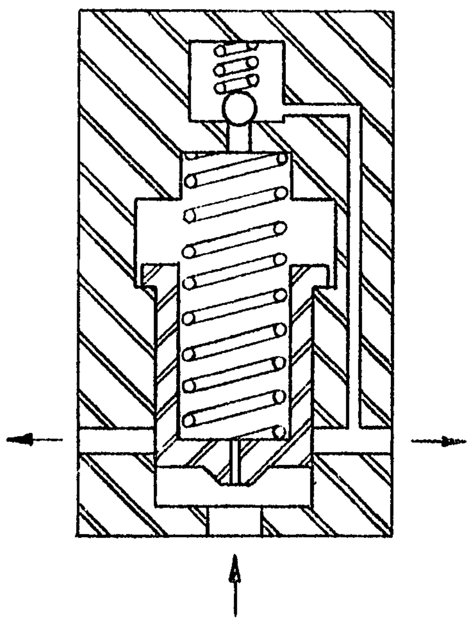
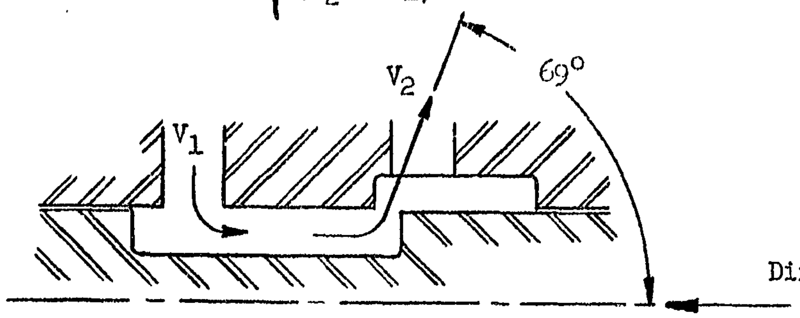


FIGURE 2
SCHEMATIC REPRESENTATION OF TWO
TYPES OF PRESSURE RELIEF
VALVES

Flow Forces - Axial forces on a valve spool are often created by the fluid flowing through the valve. This force can be calculated from the change in momentum of the fluid between inlet and outlet of the valve by the equation $F = Q\rho(V_2 - V1)$.



In this equation Q and ρ are scalar quantities while F and $(V_2 - V_1)$ are vector quantities. From the equation it can be seen that the flow force will increase as the flow rate increases. Accordingly the 25 GPM valves experienced higher flow forces than the 4 or 12 GPM valves. This must be considered in the design of components such as pressure operated shut-off valves which must open and close within a narrow actuation pressure range, for flow forces may act so as to place the full open and closing pressures outside the allowed pressure range. A very thorough analysis of axial flow forces along valve spools and experimental work to support the analysis has been presented by Dr. Lee and Dr. Blackburn of Massachusetts Institute of Technology.[6] Flow forces can be minimized by several methods. The velocity of fluid flow can be reduced by providing larger flow area with resulting decrease in the flow force. Since $V_2 - V_1$ in the above equation represents a vector subtraction, the magnitude may be reduced by changing the angles at which the fluid enters and leaves the slider groove. Then in the case of four way valves two oppositely directly forces may be made to cancel each other.

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[6] S.Y. Lee and J. F. Blackburn, "Axial Forces on Control - Valve Pistons," Meteor Report No. 65, (Massachusetts: M.I.T., 1950)

Thermal shock - Tests on two of the four way, three position selector valves (one cartridge and one face mounted) have shown that it is possible to cause a malfunction of the valve by subjecting it to a thermal shock. A rapid warm up test is included in the qualification and the units will perform satisfactorily in this test. However, if fluid which is 100°F hotter than the valve is suddenly introduced,the valve spool will expand more rapidly than the valve body, and seizure will take place within a few cycles as alternate solenoids are energized. The valve will function normally at the higher temperature when the temperature stabilizes throughout the valve. An assembly with increased clearance was found to behave similarly. It was concluded that this type malfunction can not be eliminated by increased clearance and still maintain a reasonable leakage rate. The situation described is not peculiar to these particular valves. It should be typical of many sleeveless valves or of valves in which the sleeve is shrink fitted into the valve body. It is mentioned here only because the situation is one which the system designer should be aware of.

Orifice protection - Erratic performance of the 25 GPM relief valve was obtained during development testing. This was first thought to be the result of entrapped air being released from the fluid as it passed throught the 0.015 inch diameter orifice to the pilot stage. Air was accumulated between the slave poppet and pilot poppet which was difficult to bleed from the valve. Once this occurred, a very low inlet pressure was sufficient to move the slave poppet against the cushion of air so that rated flow was passed from inlet to outlet ports. How-

ever, further investigation showed that this erratic performance was caused by partial clogging of the screen which protects the orifice. When the screen was thoroughly cleaned the valve functioned properly regardless of the quantity of air trapped. The filter screen used was an absolute 20 micron rating which is a higher degree of filtration than required in this application. Specification MIL-H-5440 requires that all orifice holes smaller than 0.070 inch diameter in flow regulators and restrictors be protected by a filter element having a screened opening of 0.008 inch to 0.012 inch. Most valve manufacturers, being aware of this requirement, utilize a filter screen to protect the orifice in valves other than restrictors and flow regulators; however, they sometimes use a screen which does not conform to the above dimensions. The requirement for a screen with a 0.008 inch minimum opening should apply to such pilot operated valves as relief valves, priority valves, and solenoid operated selector valves. Too high a degree of filtration will encourage clogging and thereby defeat the purpose of the filter.

Filter assembly differential pressure indicators - The indicator in a filter assembly is used to sense the differential pressure between the upstream and downstream sides of the filter element. The indicator design is usually based upon pressure acting upon a piston until the force becomes great enough to overcome the preload in a spring - at which time a red indicator button "pops out." Most indicator designs for low temperature applications utilize elastomers as dynamic seals on the sensing piston. Qualification of a high temperature indicator utilizing reed seals as a dynamic seal was attempted on the 4 GPM filter. While this provided no initial leakage and a low leakage rate after

endurance cycling, the design could not be considered satisfactory because of external leakage. The indicators which were ultimately qualified in the 4, 12, and 25 GPM filters were magnetic types in which both the indicator button and the actuating piston are permanent magnets separated by a thin steel wall. No external dynamic seals are required. An internal dynamic seal is still needed on the sensing piston.

Filter washout - Much effort was spent in developing filter configurations for use within the restrictor valves. All orifices smaller than 0.07 inch in diameter must be filtered, and these filters repeatedly failed during the erosion test in which flow sufficient to maintain a 5,000 psi differential pressure is passed through the orifice. Several different types of wire cloth were used. An acceptable valve was finally created by including baffle pates to disburse the flow and reduce the velocity through each filter.

IV

CONCLUSIONS

Figures 3 through 9 show photographs of the completed modular valves, the switch, and filter assemblies. Three units of each type shown have been produced for delivery to the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania, in partial fulfillment of the requirements of Contract NOas 59-6019-c. One of the three units has been subjected to the qualification tests specified in the applicable specification (see appendix). The other two units have been acceptance tested, and some have been subjected to random tests from qualification or to tests within packages. Table 4 shows the acceptance test effort for each of the units. The following documentation necessary to the establishment of a Qualified Products List has been forwarded to the Bureau of Naval Weapons, Navy Department, Washington 25, D.C.:

2 copies of each suggested MIL specification

2 copies of list of materials

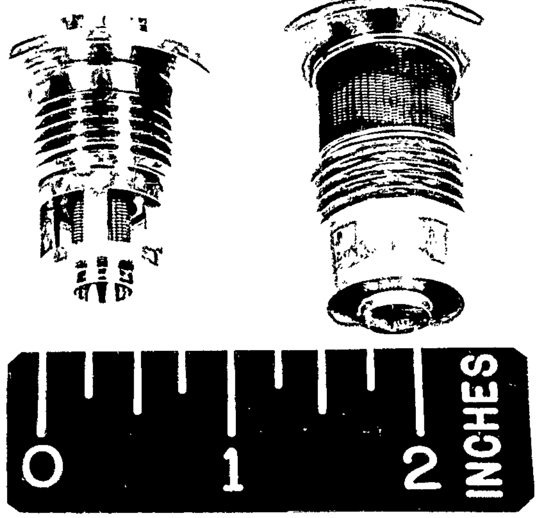
1 reproducible drawing of component

2 copies of component drawing

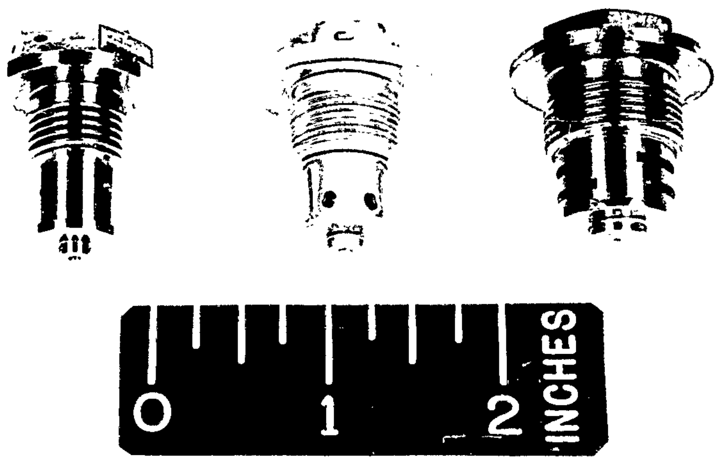
2 copies of qualification test report

2 copies of each suggested MS standard page

Each of the manufacturers listed in Table 5 is considered to be eligible for inclusion in a Qualified Products List for Type III aircraft hydraulic componentε. In addition to these components the following

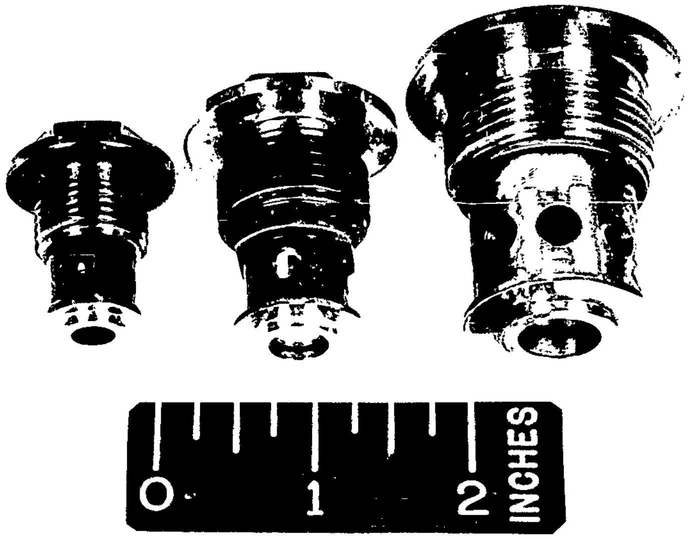


ONE WAY RESTRICTOR & TWO WAY RESTRICTOR

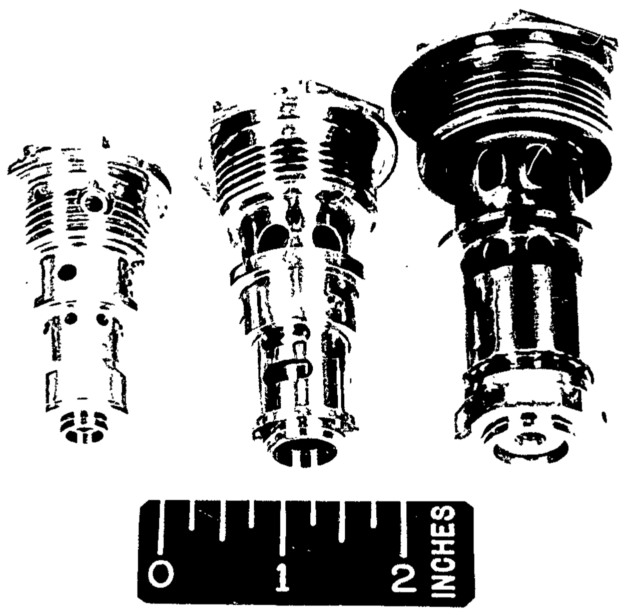


1500, 3000, & 4000 PSI SYSTEM THERMAL RELIEF VALVES

FIGURE 3
MODULAR VALVE ASSEMBLIES



4, 12, & 25 GPM CHECK VALVES



4, 12, & 25 GPM SHUTTLE VALVES

FIGURE 4
MODULAR VALVE ASSEMBLIES

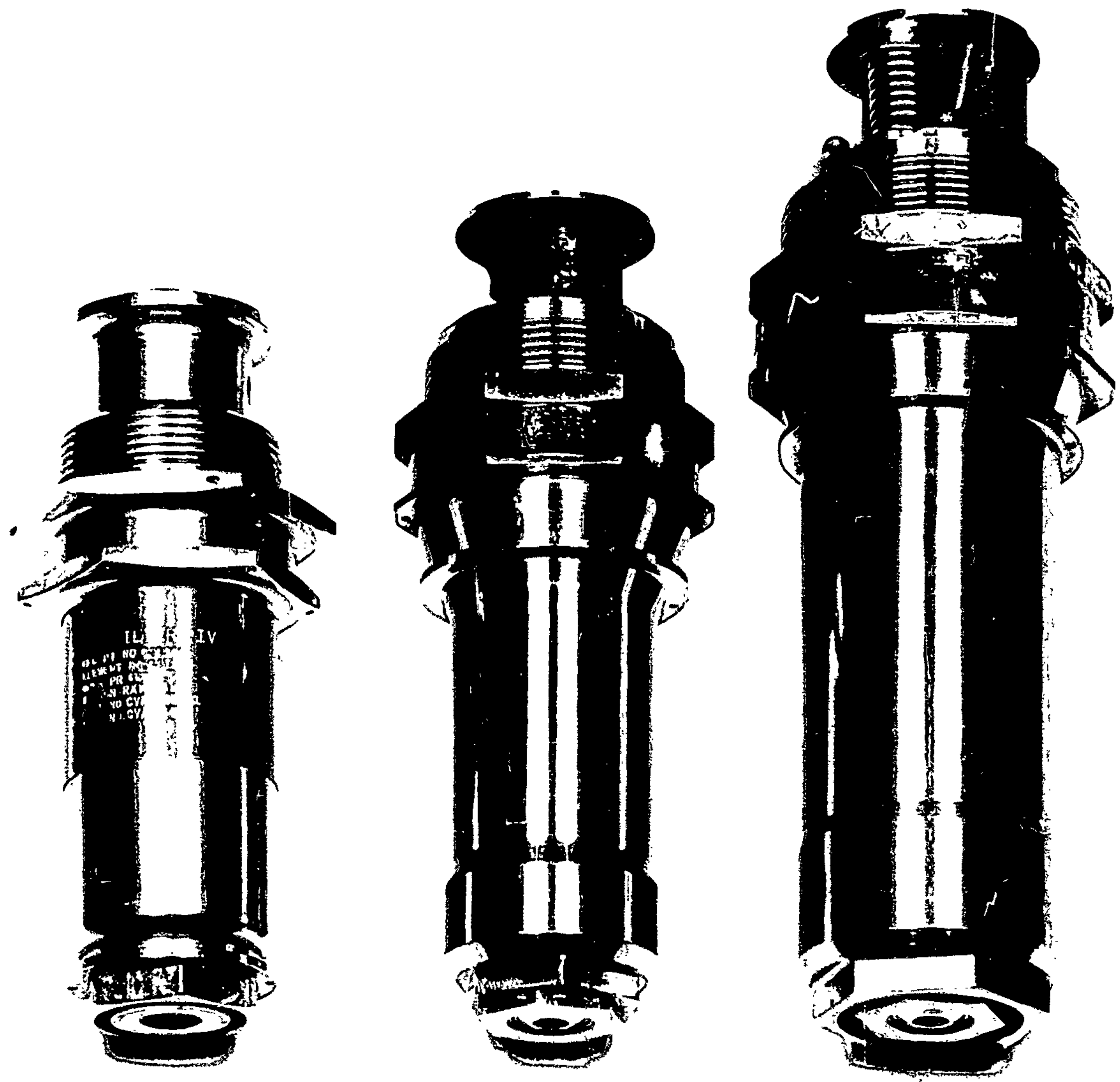
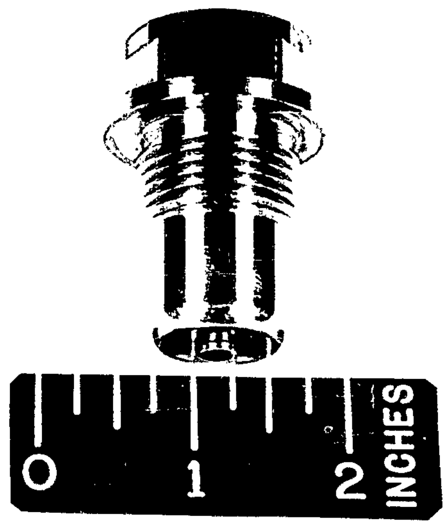
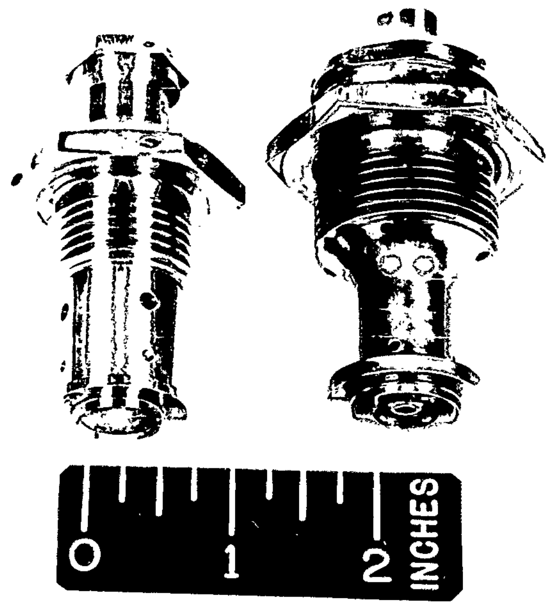


FIGURE 5
4, 12, & 25 GPM FILTER ASSEMBLIES

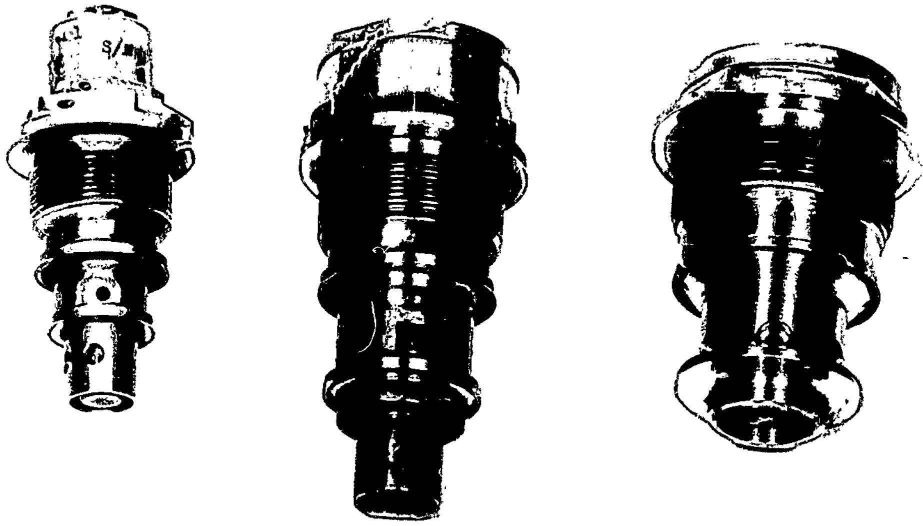


PRESSURE SWITCH

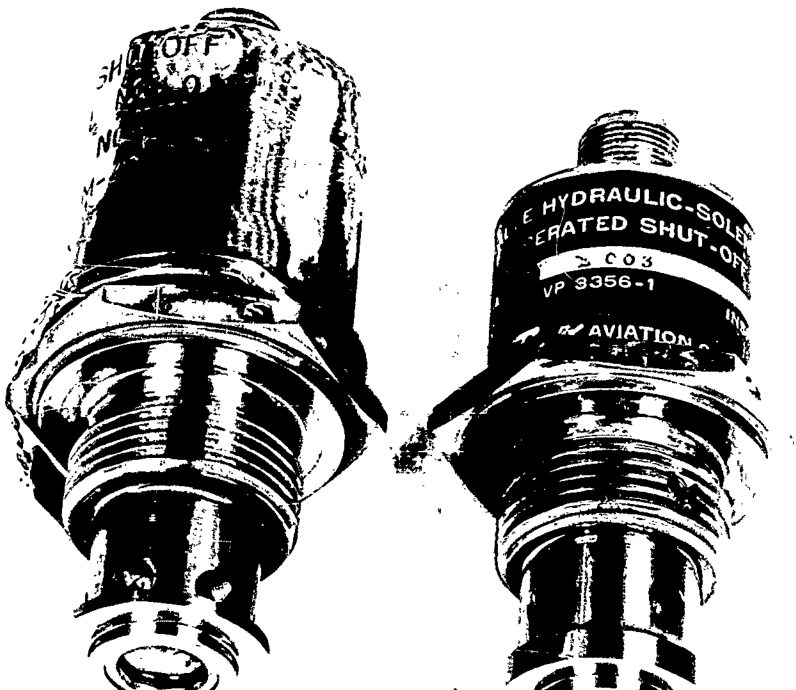


4 & 25 GPM RELIEF VALVES

FIGURE 6
MODULAR COMPONENT ASSEMBLIES

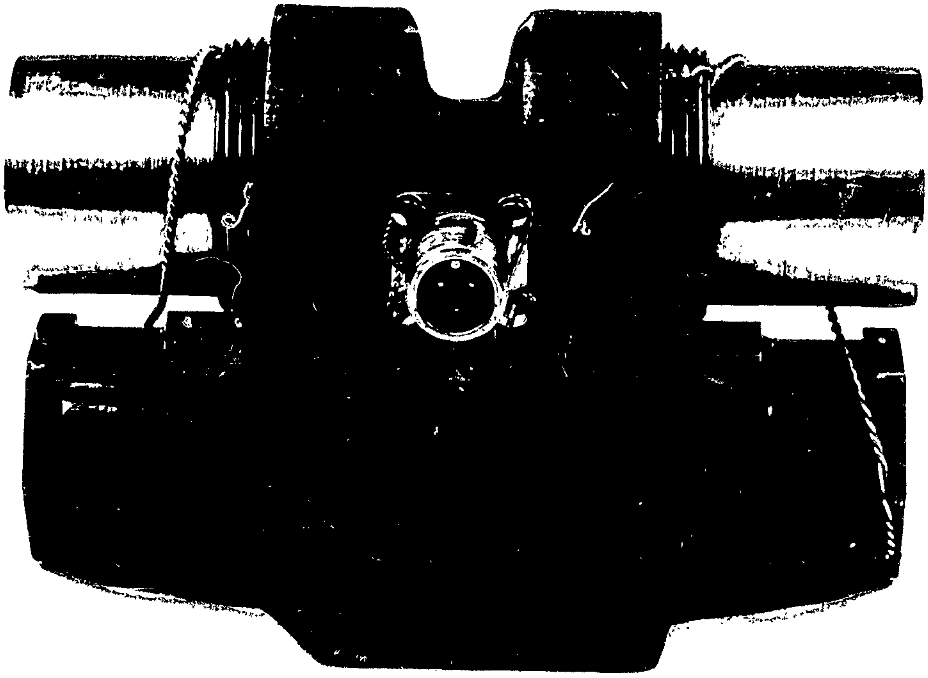


4, 12, AND 25 GPM PRIORITY VALVES

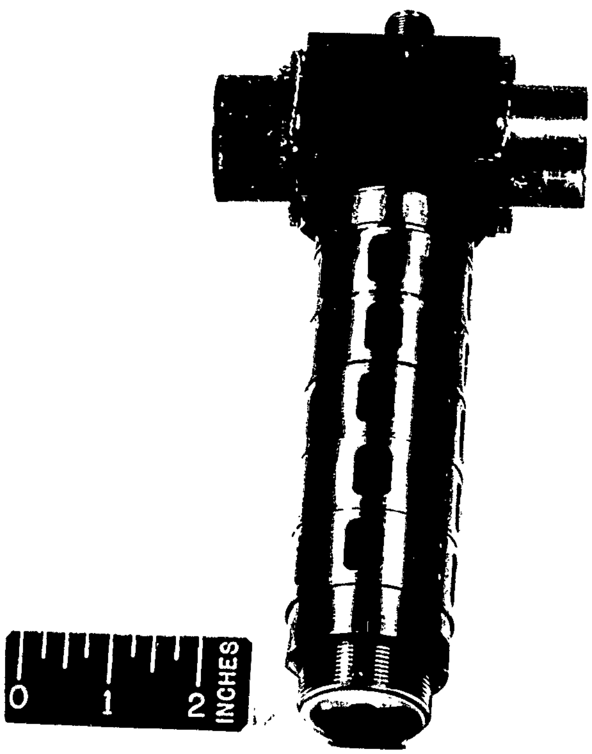


25 GPM SOLENOID OPERATED SHUT-OFF VALVES

FIGURE 7
MODULAR VALVE ASSEMBLIES

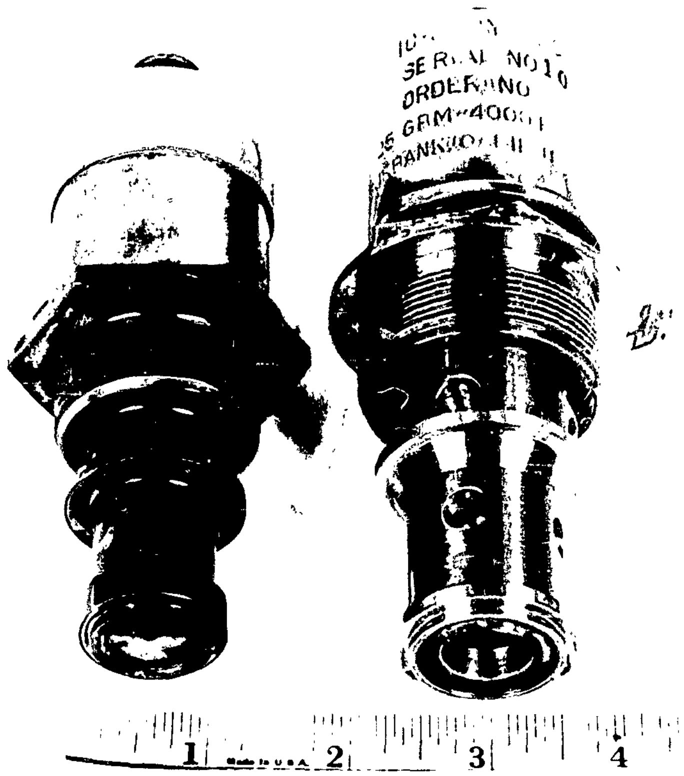


12 GPM
4 WAY, 3 POSITION SELECTOR VALVE
(FACE MOUNTED TYPE)

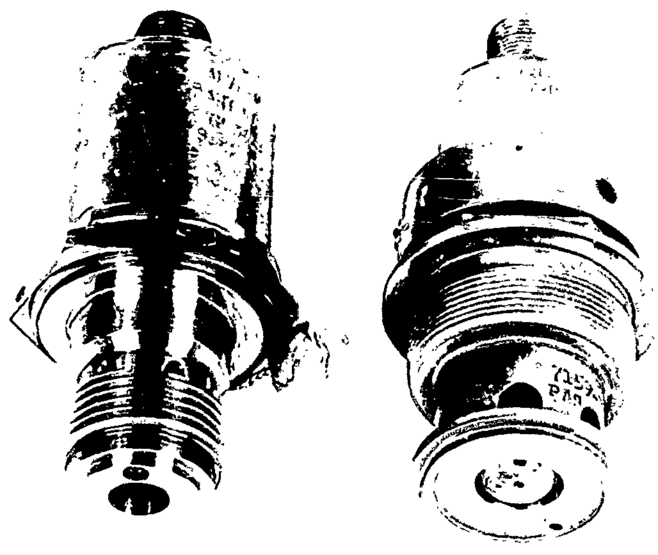


25 GPM
4 WAY, 3 POSITION SELECTOR VALVE
(CARTRIDGE TYPE)

FIGURE 8



4 AND 25 GPM SOLENOID OPERATED 3 WAY, 2 POSITION SELECTOR VALVES



12 AND 25 GPM SOLENOID OPERATED SEQUENCE VALVES

FIGURE 9
MODULAR VALVE ASSEMBLIES

TABLE 4

EVALUATION TESTS

Component	Times Test Conducted	Times Returned To Vendor	Final Configuration Acceptable	No. Of Parts Tested
1. Restrictor, 2 Way, Class B	1		Yes	1
2. " 1 Way, " A	1		Yes	1
3. Check Valve, Class A	1		Yes	1
4. " " " B	1		Yes	1
5. " " " C	3	1	Yes	3
6. Shuttle Valve, Class A	1	1	Yes	1
7. " " " B	1		Yes	1
8. " " " C	2	2	Yes	1
9. Pressure Switch	1		Yes	1
10. Thermal Relief Valve,Class A	2		Yes	1
11. " " " " B	2	1	Yes	1
12. " " " " C	1		Yes	1
13. Priority Valve, Class A	1	1	No	1
14. " " " B	2	1	Yes	2
15. " " " C	2	2	Yes	2
16. Pressure Relief Valve,Class A	1		Yes	1
17. " " " " C	3	2	Yes	3
18. Pres. Oper. Shut-Off V, Class A	3	2	No	3
19. " " " " B	3	1	No	1
20. " " " " C	0	0	-	0
21. Select.Val. 4W-3P, Class A	1	1	No	1
22. " " " " C	1		Yes	1
23. Filter, Class A	2	1	Yes	1
24. " " B	2		Yes	1
25. " " C	1		Yes	1
26. Sol. Oper. Seq. Valve, Class B				
27. " " " " " C	1		Yes	1
28. 3W-2P, Control Val, Class A	2	1	Yes	1
29. " " " " C				
30. " " " " C	1		Yes	1
31. Sol. Oper. Shut-Off V, Class C				
32. " " " " " C	1		Yes	1
33. 4W-3P, Control Valve, Class B	1		Yes	1

TABLE 5

RECOMMENDATIONS FOR QUALIFIED PRODUCTS LIST

Manufacturer	Component
Crescent Sargent Corporation	Check Valve - 4 GPM
Gar Precision Parts, Inc.	Check Valve - 12 GPM
Republic Manufacturing Company	Check Valve - 25 GPM
Ronson Hydraulic Units Corporation	One Way Restrictor
Ronson Hydraulic Units Corporation	Two Way Restrictor
Bendix-Pacific Division	Thermal Relief Valve (2100 to 3100 psi)
Fluid Regulators Corporation	Thermal Relief Valve (3100 to 4100 psi)
Altair, Inc.	Thermal Relief Valve (4100 to 5100 psi)
Consolidated Controls Corporation	Shuttle Valve - 4 GPM
Ronson Hydraulic Units	Shuttle Valve - 12 GPM
Langley Corporation	Shuttle Valve - 25 GPM
Rochester Manufacturing Company	Pressure Switch
Sargent Engineering Corporation	Priority Valve - 25 GPM
M. C. Manufacturing Company	Relief Valve - 4 GPM
Bendix - Pacific Division	2 Way, 2 Position Selector Valve - 25 GPM
Ronson Hydraulic Units Corporation	Solenoid Operated Sequence Valve - 25 GPM
Bendix - Pacific Division	4 Way, 3 Position Selector Valve - 25 GPM
Bendix - Filter Division	Filter - 4 GPM
Aircraft Porous Media	Filter - 12 GPM
Aircraft Porous Media	Filter - 25 GPM

units have completed qualification tests with some deficiency which does not meet the requirements of the applicable specification:

1. Three way, two position selector valve - (25 GPM) - Whittaker Controls

2. Three way, two position selector valve - (4 GPM) - Sargent Engineering

3. Four way, three position selector valve - (4 GPM) - Whittaker Controls

Items (1) and (2) above leaked excessively and experienced dielectric failure of the solenoid during the vibration test. The schedule for completion of Project Hydratoy does not allow time for fabrication of new valves and qualification of those units. Production valves could have these deficiencies corrected by closer control of the clearance in lap assemblies and by use of a solenoid wire which is less subject to failure than the ceramic insulated wire which was used on the prototype valves. In order that the three way valve specification be satisfied, the following qualification tests should be performed on a production valve in the order listed: (a) Leakage (paragraph 4.6.3), (b) Vibration (paragraph 4.6.12), and (c) Solenoid Current Drain (paragraph 4.6.7). Item (3) above also experienced dielectric failure in the solenoid. It requires additional testing of a redesigned solenoid to render it suitable for a qualified products list. Development problems discussed in Section III have delayed completion of the qualification tests on several valves. The following units are still undergoing tests and will be eligible for inclusion in the Qualified Products List if test results are satisfactory:

1. Relief Valve - 25 GPM - Benbow Manufacturing Co.
2. 2 Way, 2 Position Selector Valve - 25 GPM - HydroAire
3. 3 Way, 2 Position Selector Valve - 25 GPM - HydroAire
4. Solenoid Operated Sequence Valve - 12 GPM - HydroAire
5. 4 Way, 3 Position Selector Valve - 12 GPM - Ronson Hydraulic Units Corp.
6. Priority Valve - 4 GPM - Fluid Regulators Corporation

Experience in testing Type III components has led to the conclusion that 100% of the units received from the manufacturer must be subjected to acceptance tests. Many of the units received have not functioned properly even though they were fabricated in a model shop and should be expected to be of high quality. The high rejection rate may be attributed to the fact that the units are model shop parts and that standard check out procedures have not been established at the source of manufacture. Sampling procedure should not be inaugurated until a sufficient history of a design and the manufacturer of the component is accumulated to warrant testing by samples. While most of the solenoid operated selector valves were qualified with solenoids wound from a ceramic coated wire, this wire cannot be considered desirable for production valves. It can be made to work satisfactorily but only with an unreasonable degree of care in the winding of the coil. At the time the valves were designed a survey revealed that the ceramic coated wire was the only available wire which would withstand continuous operation at 650°F. Late in the program two manufacturers turned to an alternate wire known as Annaconda ML. This wire has a Dupon Herox film for insulation and

ABSTRACT

This is the final report of a research and development program sponsored by the Airborne Equipment Division of the Bureau of Naval Weapons for the development of Modular Hydraulic components and concepts. The program is informally called "Project Hydratoy" and was initiated in December of 1958. The technical monitor for the program was Mr. B. L. Mettee of the Airborne Equipment Division.

In general terms, the program's basic objectives are to:

1. Package groups of individual components into one housing to save weight and space and to gain reliability.

2. Make the use of packages more attractive and to simplify installation and maintenance by providing a standard line of self-contained cartridge-like components for use in these packages.

3. Carry this integration one step further and investigate ways and means of physically integrating the complete hydraulic system into its supporting structure.

4. Develop the above concepts for a 450°F, 4,000 psi hydraulic system using corrosion-resistant materials and metallic seals.

This report is published in four separately bound parts:

Part I contains results of metallic seal and package development.

Part II presents results of modular component development and the specifications and standards for those components.

Part III contains results of development in the integrated system concept and design criteria for that concept.

Part IV is a report of materials and process development which occurred in conjunction with and as a result of development effort in metallic seals, packages, components, and system integration.

NOTICE

ACKNOWLEDGEMENTS

Chance Vought Corporation wishes to acknowledge its indebtedness to the many companies of the hydraulic equipment industry which participated in the development of the modular components. A large number of companies submitted design proposals which were useful in establishing the envelopes for the various units. Of the companies awarded development contracts, many experienced development problems which necessitated expenditures above those for which they were compensated. While the program was not profitable for some of these, the experience gained has helped to place these organizations in a position of leadership in the field of high temperature hydraulic equipment.

The following persons have contributed to the modular component development work reported herein:

G. K. Fling - Principal Investigator
J. H. Ballantoni
C. C. Collier
J. R. Moore

CONTENTS

Page

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

The modular hydraulic program was initiated for the purpose of improving aircraft hydraulic systems through the use of the packaged system concept. The potential improvements to be realized are: a reduction in space requirements; improved system reliability through reduction in leak points; improved system maintenance; reduction in system weight; and reduced logistical effort through standardization of components.

The objective of Phase II was to develop and qualify a series of modular hydraulic components for application in Type III, packaged systems. It was required that the components be capable of continuous operation in MLO-8200 fluid at 450°F with ambient temperature of 650°F. The development and qualification of the series of components was accomplished through the combined efforts of Chance Vought Corporation and a large segment of the hydraulic equipment industry. A total of twenty components have successfully completed qualification tests and are suitable for use in Type III systems with growth potential for Type IV systems.

I

DESIGN PHILOSOPHY

Previous hydraulic package designs had been for specific applications with no attempt to standardize the valves which, with a manifold, made up the package. The objective of this phase was to develop and qualify sample units of a selected list of hydraulic components which are used in most systems. Originally a high temperature capability of 400°F was selected for this program to agree with the temperature range arbitrarily established for the Type III system. However, when it became apparent that actual aircraft being developed by North American Aviation for the Air Force would require 450°F capability, it was decided that an increase to this value would result in more usable standards. This decision meant that the valves had to be designed around metallic seals rather than elastomeric seals and that MLO-8200 hydraulic fluid would be used instead of MLO-8515 fluid. The nominal system pressure was selected to be 4,000 psi. Burst pressure was taken as 10,000 psi at room temperature while proof pressure was taken as 6,000 psi at 450°F.

In order to coordinate the development work being done on the modular hydraulics program with the weapon systems being designed by both Air Force and Navy Contractors, an industry conference was held at Chance Vought on January 19th and 20th, 1959. In addition to the previously mentioned ground rules the following decisions were reached at the conference:

(1) Vibration tests will be required as a part of qualification of each component.

(2) Components must be capable of operation with the fluid temperature from -65 to + 450°F but should not be required to meet response requirements, pressure drop requirements, et cetera, below -20°F.

(3) The usual 168 hour soak at high temperature is not required as a part of qualification since metallic seals are used in place of elastomeric seals.

(4) The components should be a stepped configuration with the metallic seals located on these steps. The step design makes it impossible to install a valve backward in a manifold.

(5) Only one unit of each type and size need undergo qualification. Maximum and minimum tolerance units are usually qualified to verify the design under conditions of varying "O" ring squeeze. This, it was felt, is not necessary when metallic seals are used. A mathematical analysis of clearances is required to show that seizure of mating parts will not occur when the parts are made to the extremes of tolerance permitted by detail drawings.

The components selected for development are listed in Table 1. Many of these units were developed in several sizes to handle different flow rates (0 to 4 GPM, 4 to 12 GPM, or 12 to 25 GPM) or different pressure ranges. Each unit was designed to incorporate a different size thread or some other device to prevent one unit from inadvertently being installed in the cavity intended for a different type of component. This feature should improve system reliability by making it impossible for

TABLE 1

COMPONENTS SELECTED FOR DEVELOPMENT

Components	Sizes	Number of Vendor Contracts	Total Units
(1) thermal relief valve	3	3	9
(2) pressure relief valve	2	2	6
(3) check valve	3	3	9
(4) shuttle valve	3	3	9
(5) one way restrictor	1	1	3
(6) two way restrictor	1	1	3
(7) filter	3	3	9
(8) priority valve	3	3	9
(9) pressure operated shut-off valve	3	3	9
(10) pressure switch	1	1	3
(11) solenoid operated sequence valve	2	2	6
(12) solenoid operated shut-off valve	1	2	6
(13) solenoid operated 3 way 2 position valve	2	3	9
(14) solenoid operated 4 way 3 position valve	3	3	9
Totals	31	33	99

maintenance personnel to install the wrong valve or to install a given valve backwards. Each cartridge valve has been designed as a self-contained component which may be removed from one package and installed in another without disassembly, readjustment of setting, or impairment of function. Many packaged systems utilize an approach wherein poppets, springs and other items making up a valve are assembled directly into the package instead of being self-contained. This approach is not compatible with the goals of standardization, ease of system maintenance, reliability, and low overall cost which are possible through the packaged system concept.

Components are generally qualified in exceptionally clean systems which are not typical of the systems in operational aircraft. It is desirable that components be qualified in a system which is as much as possible like the system in which they will be used. To assure that the modular valves would be tolerant of contamination, a controlled amount of contaminant was added to the qualification test systems.

A cavity was established for each component to assure proper fit of the module in the package and proper squeeze on the metallic seals. These cavities may be seen in the suggested MS pages enclosed in the appendix to this report. To eliminate the possibility of installing the wrong size or type component, each cavity differs for all sizes and types of component. A thin-walled test housing was designed for each component and forwarded to the vendors as suggested test housings for qualification tests. The thin-walled test housing simulates the type of manifold which is used in flying hydraulic systems.

II

DEVELOPMENT PROCEDURE

Immediately following the conference of Naval, Air Force, and airframe manufacturer representatives a symposium was held with 150 representatives of the hydraulic equipment industry to present a briefing on Project Hydratoy, to exchange ideas, and to gather opinions. At this symposium a minimum requirement specification was distributed to all interested vendors and non-competitive, preliminary proposals were invited to aid in establishment of envelopes. Upon receipt of these preliminary proposals Chance Vought Corporation began an evaluation with a view toward determining the minimum reasonable envelope for the most feasible designs proposed. A procurement specification and an envelope control drawing were then prepared for each component. These were sent to each vendor who submitted a preliminary proposal. Upon receipt of the final proposals the bids were reviewed, designs were reviewed, and a selection of vendors was made jointly by the Bureau of Naval Weapons and Chance Vought Corporation. Table 2 lists the manufacturers who submitted a proposal on each specific valve. Contract awards were then made for the development and qualification of the components. Each contract specified that three components of each type were to be manufactured. One became the qualification unit while the other two were subjected to acceptance tests by Chance Vought. The knowledge gained throughout the development and qualification programs was fed back for incorporation into the MIL type specification and MS type drawing which has been prepared for each component. The complete set of specifications and suggested MS standards may be seen in the appendix to this report.

In establishing the envelope for these valves, the preliminary proposals received were placed on charts to facilitate comparison. These were then reviewed to determine those designs which best met the requirements of the applicable procurement specification. They were then narrowed down to a single design or usually a composite design around which an envelope could be established. The design approach selected was modified to accept metallic seals of the sizes listed in specification CVC 2464 (see appendix, Part 1 of this report). The design was further modified to affect miniaturization. Consideration was given to the flow area requirements around all valve ports which would enable the valve to pass rated flow without exceeding the allowable pressure loss. A nominal fluid velocity of 25 feet per second was used as a guide in determining the size of the various valves. It was originally planned that three sizes of valve would be developed in the pressure relief valve, solenoid operated shut-off valve, solenoid operated sequence valve, and the solenoid operated 3-way, 2-position valve. Each size was intended to cover one of the flow rates 0 to 4 GPM, 4 to 12 GPM or 12 to 25 GPM. Design layouts were made for each flow rate; however, the increment of increase in dimensions was so small between one class and the next that three separate valve standards are not warranted. In the case of the solenoid operated valves the solenoid is the same size regardless of the flow capacity of the main stage. It can be seen that the solenoid and the pilot stage, which together comprise the bulk of a valve, are unaffected by flow rate. Only the size of the main stage increases for higher flow rates.

TABLE 2

LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT

CHECK VALVE	RESTRICTOR
Accessory Products Company	Accessory Products Company
Air Products Company	Air Products Company
Altair, Inc.	Altair, Inc.
Benbow Manufacturing Company	Benbow Manufacturing Company
Com-Air Products	Com-Air Products
Conair, Inc.	Conair, Inc.
Crescent-Sargent Corporation	De Coto Brothers
Crissair	Gar Precision Parts
De Coto Brothers	Hydro-Aire, Inc.
Fluid Regulators Corporation	Integral Corporation
Gar Precision Parts	Langley Corporation
Hydro-Aire, Inc.	Lear, Inc.
Integral Corporation	M.C. Manufacturing Company
James, Pond and Clark, Inc.	Pantex Manufacturing Company
Langley Corporation	Pneudraulics, Inc.
Lear, Inc.	Republic Manufacturing Company
M.C. Manufacturing Company	Randall Engineering Corporation
Pantex Manufacturing Company	Ronson Hydraulic Units
Pneudraulics, Inc.	Vinson Manufacturing Company
Republic Manufacturing Company	The Weatherhead Company
Randall Engineering Corporation	

TABLE 2 LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT (Continued)

<u>CHECK VALVE</u>

Ronson Hydraulic Units

Vinson Manufacturing Company

The Weatherhead Company

<u>THERMAL RELIEF</u>

Altair, Inc.

Benbow Manufacturing Company

Bendix-Pacific Division

Besler Corporation

Com-Air Products

Fluid Regulators Corporation

Gar Precision Parts

Hydra-Power Corporation

Hydraulic Research

M. C. Manufacturing Company

Pantex Manufacturing Company

Parker Aircraft Company

Pneudraulics, Inc.

Republic Manufacturing Company

Randall Engineering Corporation

Sargent Engineering Corporation

Tavco, Ltd.

Vinson Manufacturing Con y

<u>SHUTTLE</u>

Altair, Inc.

Benbow Manufacturing Company

Com-Air Products

De Coto Brothers

Hydro-Power Corporation

Langley Corporation

M.C. Manufacturing Company

Parker Aircraft Company

Randall Engineering Corporation

Ronson Hydraulic Units

Sargent Engineering Corporation

Vinson Manufacturing Company

The Weatherhead Company

<u>PRIORITY VALVE</u>

Adel Precision Products

Bendix-Pacific Division

Com-Air Products

Fluid Regulators Corporation

TABLE 2 LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT (Continued)

<u>THERMAL RELIEF</u>

The Weatherhead Company

<u>SEQUENCE VALVE</u>

Altair, Inc.

Bendix-Pacific Division

Com-Air Products

Hydro-Aire

Ronson Hydraulic Units

<u>RELIEF VALVE</u>

Adel Precision Products

Altair, Inc.

Benbow Manufacturing Corporation

Bendix-Pacific Division

Carleton Aviation

Com-Air Products

Fluid Regulators Corporation

M. C. Manufacturing Company

Pneudraulics, Inc.

Republic Manufacturing Corporation

Sargent Engineering Corporation

Tavco, Ltd.

Vinson Manufacturing Company

The Weatherhead Company

Whittaker Controls

<u>FOUR-WAY VALVE</u>

Altair, Inc.

<u>PRIORITY VALVE</u>

Hydra-Power Corporation

Hydro-Aire

Parker Aircraft Company

Sargent Engineering Corporation

Vinson Manufacturing Company

<u>PRESSURE SHUT-OFF</u>

Adel Precision Products

Altair, Inc.

Bendix-Pacific Division

Com-Air Products

Fluid Regulators Corporation

Hydra-Power Corporation

Hydro-Aire, Inc.

Republic Manufacturing Company

Randall Engineering Corporation

Ronson Hydraulic Units

Sargent Engineering Corporation

Tavco, Ltd.

Vinson Manufacturing Company

Waldorf Instrument Company

The Weatherhead Company

<u>PRESSURE SWITCH</u>

Aircraft Controls Company

TABLE 2 LIST OF MANUFACTURERS SUBMITTING PROPOSALS ON EACH MODULAR COMPONENT (Continued)

FOUR-WAY VALVE

Bendix-Pacific Division

Hydro-Aire

Ronson Hydraulic Units

Sargent Engineering Corporation

Whittaker Controls

Weston Hydraulics, Ltd.

PRESSURE SWITCH

Benbow Manufacturing Corporation

Century Electronics

Cook Electric Company

Randall Engineering Corporation

Rochester Gage Company

THREE-WAY SELECTOR VALVE

Adel Precision Products

Altair, Inc.

Bendix-Pacific Division

Hydra-Power Corporation

Hydro-Aire, Inc.

Moog Servocontrols, Inc.

Parker Aircraft, Inc.

Randall Engineering Corporation

Ronson Hydraulic Units

Sargent Engineering Corporation

Vinson Manufacturing Company

Whittaker Controls

TWO-WAY SELECTOR VALVE

Adel Precision Products

Altair, Inc.

Bendix-Pacific Division

Com-Air Products

Hydra-Power Corporation

Hydro-Aire, Inc.

Marotta Valve Corporation

Parker Aircraft Corporation

Randall Engineering Corporation

Ronson Hydraulic Units Corporation

Sargent Engineering Corporation

Vinson Manufacturing Company

FILTER ASSEMBLY

Aircraft Porous Media

Bendix - Filter Division

Permanent Filter Corporation

Development contracts were awarded to component suppliers as noted in Table 3.

In the development program for each component listed above, the manufacturer was required to submit, for approval, a qualification test procedure and a test housing design. The development program was monitored through qualification and approval of the qualification test report.

TABLE 3

LIST OF MANUFACTURERS AWARDED DEVELOPMENT CONTRACTS

Check Valve	4 GPM	Crescent Sargent Corporation 5543 E. Admiral Place Tulsa, Oklahoma
(Qualification performed by Aerotest Laboratories)		
Check Valve	12 GPM	Gar Precision Parts, Inc. 36 Ludlow Street Stanord, Connecticut
(Qualification performed by Aerotest Laboratories)		
Check Valve	25 GPM	Republic Manufacturing Company 15655 Brookpark Road Cleveland 11, Ohio
(Qualification performed by Aircraft Equipment Testing Company)		
One way restrictor	0 to 4 GPM	Ronson Hydraulic Units Corporation 1313 Lincoln Avenue Pasadena, California
Two way restrictor	0 to 12 GPM	Ronson Hydraulic Units Corporation
Thermal relief valve	2100 to 3100 psi	Bendix-Pacific Division 11600 Sherman Way North Hollywood, California
Thermal relief valve	3100 to 4100 psi	Fluid Regulators Corporation 313 Gillette Street Painesville, Ohio
(Qualification performed by Wyle Parameters Laboratories)		
Thermal relief valve	4100 to 5100 psi	Altair, Incorporated 50 St. McQuesten Pkwy. Mt. Vernon, New York
(Qualification performed by Aerotest Laboratories)		
Shuttle Valve	4 GPM	Consolidated Controls Corporation 750 S. Isis Avenue Englewood, California
(Qualification performed by Garwood Laboratories)		
Shuttle Valve	12 GPM	Ronson Hydraulic Units Corporation
Shuttle Valve	25 GPM	Langley Corporation 310 Euclid Avenue San Diego, California
(Qualification performed by Garwood Laboratories)		

TABLE 3 (Continued)

Pressure Switch		Rochester Manufacturing Co. Rochester, New York
Three way selector valve	4 GPM	Sargent Engineering Corporation 2533 East 56th Street Huntington Park, California
Three way selector valve	25 GPM	Hydro-Aire, Inc. 3000 Winona Avenue Burbank, California
(Qualification performed by Ronson Hydraulic Units Corp.)		
Three way selector valve	25 GPM	Whittaker Controls 915 North Citrus Ave. Los Angeles 38, California
Priority valve	4 GPM	Fluid Regulators Corporation 313 Gillette Street Painesville, Ohio
(Qualification performed by Wyle Parameters)		
Priority valve	12 GPM	Hydra Power Corporation Pine Court New Rochelle, New York
(Qualification performed by Aerotest Laboratories)		
Priority valve	25 GPM	Sargent Engineering Corporation
Pressure operated shut-off valve (Not qualified)	4 GPM	The Weatherhead Company 300 E. 131st Street Cleveland, Ohio
Pressure operated shut-off valve (Not qualified)	12 GPM	Hydra Power Corporation
Pressure operated shut-off valve (Not qualified)	25 GPM	Republic Manufacturing Corporation
Relief valve	4 GPM	M. C. Manufacturing Company P. O. Box 126 Lake Orion, Michigan
(Qualification performed by Aircraft Equipment Testing Company)		

TABLE 3 (Continued)

Relief valve	25 GPM	Benbow Manufacturing Company 11920 Jefferson Boulevard Culver City, California
(Qualification performed by Chance Vought Corporation)		
Solenoid operated shut-off valve	25 GPM	Bendix-Pacific Division
Solenoid operated shut-off valve	25 GPM	Hydro-Aire
(Qualification performed by Ronson Hydraulic Units Corp.)		
Solenoid operated sequence valve	12 GPM	Hydro-Aire
(Qualification performed by Ronson Hydraulic Units Corp.)		
Solenoid operated sequence valve	25 GPM	Ronson Hydraulic Units Corporation
4 way, 3 position selector valve (cartridge type)	4 GPM	Whittaker Controls
4 way, 3 position selector valve (face mounted type)	12 GPM	Ronson Hydraulic Units Corporation
4 way, 3 position selector valve (cartridge type)	25 GPM	Bendix-Pacific Division
Filter	4 GPM	Bendix-Filter Division 434 West 12 Mile Road Madison Heights, Michigan
Filter	12 GPM	Aircraft Porous Media Glen Cove, New York
Filter	25 GPM	Aircraft Porous Media

III

DEVELOPMENT PROBLEMS

Numerous problems have been experienced by the manufacturers having development contracts. Problems, however, are to be expected when an advance in the state of the art is attempted to produce components which operate at higher temperatures and pressures and which are produced in new configurations.

The problem which has occurred most frequently is that of seal leakage. Many of the component manufacturers had little or no experience with metallic seals prior to the Project Hydratoy program. Surface finish and amount of squeeze must be controlled much more closely for metallic seals than for elastomeric seals. It was necessary to develop an awareness of minute details which are essential to the satisfactory performance of a metallic seal. The force required to compress the seal is large; consequently, components were often assembled by torquing parts together until the torque was felt to be sufficient. This method of assembly is not dependable, for the seals were frequently not compressed enough to affect a leakproof joint. Each assembly is designed to impart the proper squeeze to the seal when the mating parts bottom out on each other. Therefore, the recommended assembly procedure is as follows. The parts should be assembled without any seals until they bottom out on each other. An index mark should be placed on the two parts to indicate the position where bottoming occurs. The part should then be disassembled and reassembled using the proper seals. Sufficient torque must be applied to align the scribe marks. In

some of the larger components where multiple seals are compressed on installation, the torque may become excessive and cause thread galling. This can be prevented by presetting each seal individually. Presetting a seal consists of installing only one seal at a time and bottoming out the parts so that the seal takes a permanent set. A thread lubricant is also desirable. With proper attention to the details of manufacturing and assembling parts, excellent results can be expected from the Hi Ceal.

Cartridge configuration - A second problem has occurred on several slide type valves which does not exist in a conventional or non-cartridge valve. The cartidge valve allows flow and pressure around the outside of the valve body. As shown in Figure 1 the slider can be so positioned that the pressure on the outside of the body is not balanced by an equal pressure inside the body. The valve body (part number 2) is thus made to contract because of this differential pressure and seize the slider (part number 1). In the conventional valve pressure is always contained within the valve body so that the effect of pressure is to increase the clearance between body and slider. This type of piston seizure occurred on all three sizes of the pressure operated shut off valves which were developed. The three sizes were each developed by a different manufacturer although the designs were somewhat similar. Each unit could be made to open and close within a very narrow range of actuation pressures so long as the inlet pressurization was low. However, as the inlet pressure was increased to 4,000 psi the actuation pressure required to open the valve became larger while the actuation pressure required to close the valve was reduced. At times certain ones of the valves tested at Chance Vought remained fully open with complete

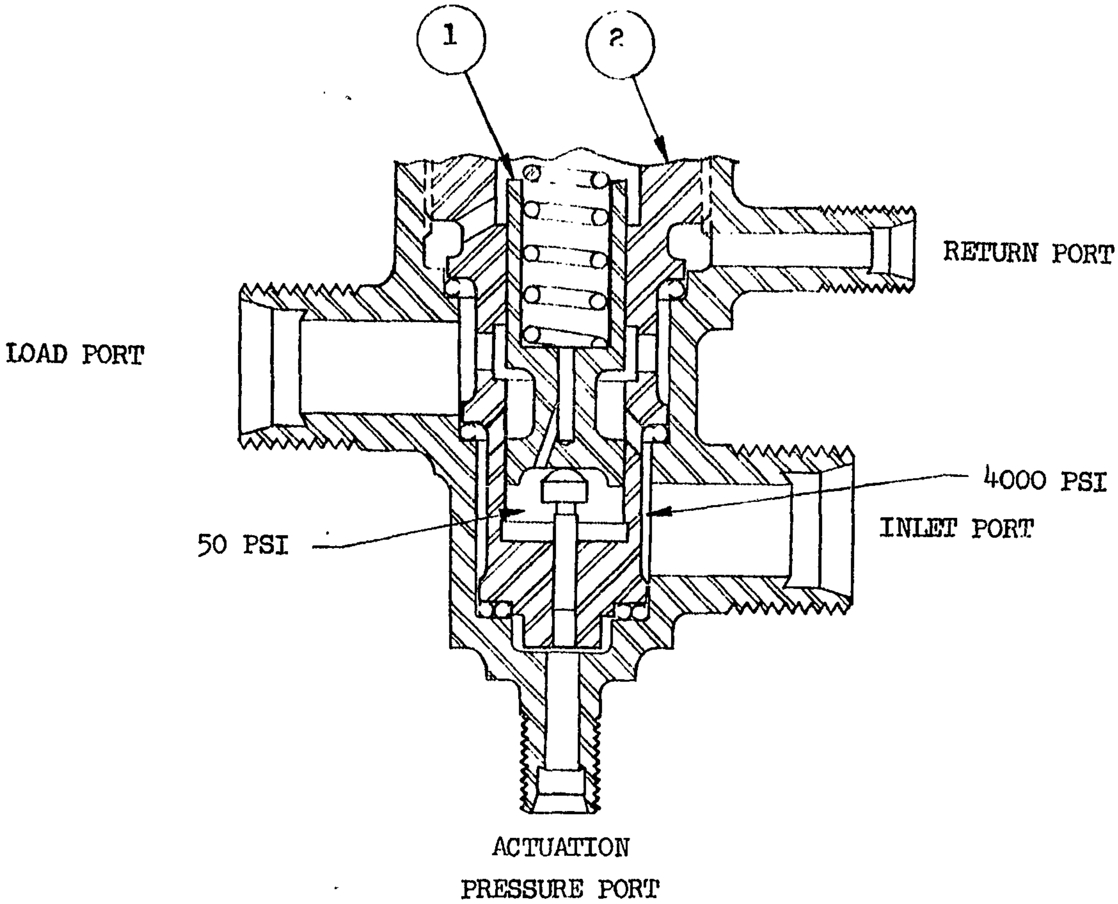


FIGURE 1

TYPICAL PRESSURE OPERATED SHUT-OFF VALVE INSTALLED IN TEST MANIFOLD

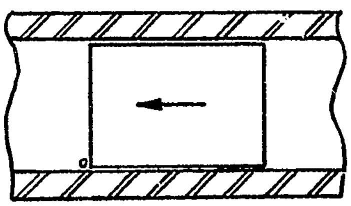
removal of the actuation pressure until the inlet port pressurization was reduced. Late in the program it became apparent that the shut off valves could not be made to function satisfactorily without a complete redesign. It was calculated that contraction of the valve body diameter due to external pressure was of a magnitude of 0.0002 inch. None of the three valve designs were successful in passing qualification tests. Both the suggested MIL specification and MS standard page for the pressure operated shut off valve are enclosed in the appendix. It is possible that relocation of the seals from the positions shown might made a redesign easier to accomplish.

Lapped fits - There is much to be said on the subject of lapped fits. Since there is no really good dynamic seal suitable for the environment specified, lapped fits are utilized extensively within these valves to eliminate dynamic seals. Some of the many facets of lapped fits which have been of concern in the modular program will be discussed.

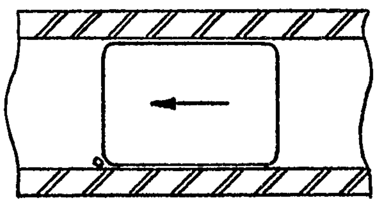
Hydraulic lock - Several selector valves experienced hydraulic lock causing the slider to hang in one position or another during development tests. Hydraulic lock is a relatively high static friction force which is produced by pressure acting on one side of the slider - forcing the slider against one wall of the valve body. The force, normal to the axis of the slider, may be reduced by the addition of labyrinth grooves in the slider. The addition of labyrinth grooves is quite effective in overcoming hydraulic lock. A surprisingly large number of valve manufacturers design valve spools without grooves in the lands. The grooves

are added only after hydraulic lock has occurred on a given design. This is probably because the research work which has been performed relative to hydraulic lock is not widely known. Some experimental work has been done to determine the variation of breakout force with the number of the grooves.[1] A quantitative theory of the pressure distribution and the resulting land force for various land configurations has also been developed.[2] Some designers add grooves in an attempt to reduce leakage rate - the theory being that grooves help to keep the spool concentric within the valve body. Other designers dispute this, and there seems to be little evidence to support the theory that the labyrinth grooves reduce leakage rate of an incompressible fluid.

Lap damage from contamination - Galling and seizure of lap assemblies sometimes occur because of contaminant being wedged into the clearance between spool and valve body. The land should intersect the groove of a spool with a sharp corner to reduce the tendency of galling from this cause.



Particles larger than about 5 Microns unable to get into clearance gap.



With radius on spool, larger particles can wedge into clearance gap.

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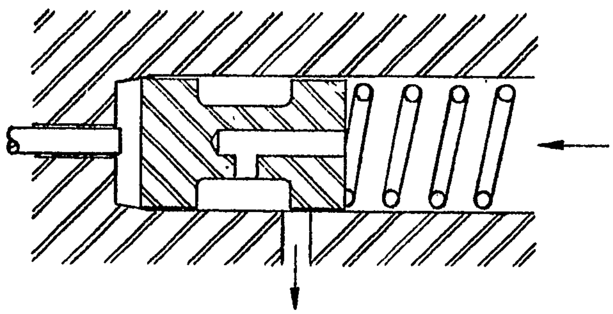
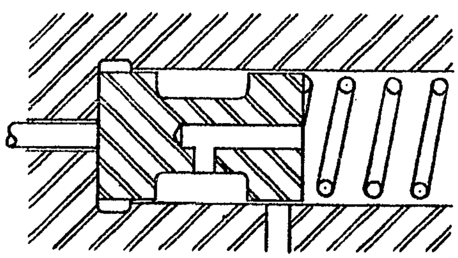
[1] D. C. Sweeney, "Preliminary Investigation of Hydraulic Lock," Engineering, Vol. 172 (1951), pp 513-516 and 580-582.

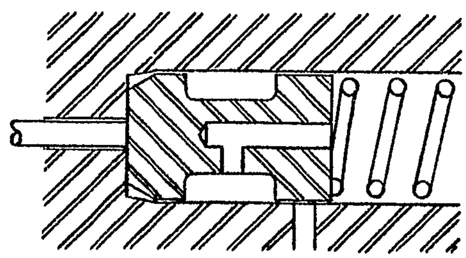
[2] J. F. Blackburn, G. Reethof and J. L. Shearer, Fluid Power Control, (New York: Wiley and Technology Press of M.I.T., 1960), pp 279-289.

Blind laps - Manufacturing problems arose on several valves in which the female part was designed as a blind lap. This was caused by the designer failing to allow sufficient room for the lead taper on the lapping tool. Excessive leakage occured because the valve spool could not reach the intended shut-off position.



Blind laps presented no problem where a relief was provided on either the spool or the bore as shown below.





Leakage rate - Leakage rates are predicted through calculations in the detail design of any valve. The equation used to calculate leakage rate from an annular flow path shows that the leakage varies inversely as the absolute viscosity of the fluid.

$$Q = \frac{\pi D\ b^3\ \left(1 + 1.5\left(\frac{E}{b}\right)^3\right)\ (Pu - Pd)}{12\,\mu\,L}$$ [3]

where μ = fluid viscosity, lb sec/sq in
Q = volume flow rate, cu in/sec.
D = diameter of passage, inch
b = passage height, inch
Pu = upstream pressure, lb/sq. in
Pd = downstream pressure, lb/sq in
L = passage length (in direction of flow), inch
E = eccentricity of spool within sleeve, inch

The kinematic viscosity of Oronite 8200 fluid is approximately 35 centistokes at 90°F and 3 centistokes at 450°F while the density is approximately 0.925 gms/cc at 90°F and 0.765 gms/cc at 450°F.[4] Using these values, the absolute viscosity may be determined to be 34.8×10^{-5} lb. sec/sq in at 90°F and 2.47×10^{-5} lb. sec/sq in at 450°F. The viscosity change corresponding to this temperature change is in the ratio 14 to 1. The equation shown above then indicates that leakage rate will be approximately 14 times as great at 450°F as would be experienced at 90°F in the same parts. In practice the leakage rate has not changed by an amount approaching the calculated change. In tests of lapped valves, the leakage rate at 450° has been from 1 to 2.5 times the values recorded at 90°F. Certainly pressure as high as 4,000 psi alters the viscosity, but no data is available. The values of viscosity quoted above are for atmospheric pressure. Also the length of the waiting period before measurement is begun greatly affects the rate which will be measured. Even in well filtered systems, silting will

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[3] Ibid., p. 58

[4] N.W. Furby, R. L. Peeler and R. I. Stirton, "Oronite High-Temperature Hydraulic Fluids 8200 and 8515," A.S.M.E. paper No. 56--AV-22, (New York:A.S.M.E., 1956), Figs 3,4.

occur to a degree sufficient to lower the leakage rate. The amount of contaminant in the system will thus affect the leakage rate measured in acceptance testing a lapped hydraulic valve.

Part distortion - The four way, three position selector valve has been developed in two configurations: (1) face mounted and, (2) cartridge. The main stage of each valve type is a lap assembly made up of a slider and the valve body. Very small deflections in the valve body are sufficient to cause seizure of the slider. Therefore, the face mounted valve must be mounted onto a manifold having a relatively flat face. In the development of the cartridge-type four way valve the radial, wedge seals introduced sufficient body distortion to create a sticking slider. It was concluded that the concept of a low leakage valve (i.e. 4cc/min) is not compatible with the tolerances which are reasonable for the wedge seals. The clearance between slider and valve body was ultimately increased until sticking of the slider no longer occurred. The internal leakage rate allowed was then increased proportionally. Measurements of one valve body showed that the wedge seals were forcing the body to go out of round by only 0.00009 inch, yet this was sufficient to cause seizure of the spool before the clearance was increased.

Wear of lap assemblies - Certain combinations of materials and surface treatments have been found to be successful in the slider and body making up a lap assembly. Some of the combinations which have demonstrated good wear resistance in qualification tests are listed below.

Body Material	Plating	Slider Material	Surface Treatment
17-4PH	None	17-4PH	Nitrided
17-4PH	None	17-4PH	Tungsten carbide
416	None	440C	Chrome
440C	None	440C	Chrome
440C	None	440C	Tufftride
440C	None	440C	None

Some attempts were made to use an unplated stainless steel against a stainless steel which was neither plated nor case hardened, and in several cases this was successful; however, this is not recommended for lap assemblies which are to operate in a fluid having relatively poor lubricity. Experience with bare lap assemblies varied from failures as disasterous as galled parts to only a more pronounced tendency toward hydraulic lock of the mating parts. Side loads, created by imperfect parts, flow forces, or the presence of contaminant, will promote failures of these types. Unplated assemblied have been very satisfactory for the type of valves wherein the clearance is 0.001 to 0.002 inch.

Dimensional stabilization - Three valves are known to have malfunctioned because of dimensional changes in the finished parts, and it is suspected that this was the cause of other failures. An adequate stabilization procedure should be contained in each valve manufacturer's heat treatment specification, inasmuch as the provisions of specification MIL-H-6875 are not sufficient for a lap assembly. Each of the valves in which this problem was evident had one or both parts making up the lap assembly made from 440C. The Metals Handbook, in discussing martensitic stainless steels, says "The higher-carbon martensitic grades such as 440C are likely to retain large amounts of untransformed austenite in the as quenched structure, frequently as much as 30% by volume. Stress

relieving at 300°F has little effect, since higher temperatures are required to achieve transformation. Delayed transformation may occur as a result of temperature fluxuations in service, thus resulting in embrittlement and serious dimensional changes. A portion of this retained austenite may be transformed by subzero cooling to about -100°F immediately after quenching. If some decrease in hardness can be tolerated, the steel should be stress relieved at a higher-than-normal temperature, preferably near 700°F. Two complete cycles of stress relieving are advisable, regardless of the temperature used. In combination with the higher stress-relieving temperature, the subzero treatment is less useful, although both treatments are recommended for maximum stability. In general, the high-carbon grades should be tempered at a temperature at least as high as that to which they will be subjected in service."[5] This situation is discussed further in Part IV of this report. It should be noted that a number of the valve manufacturers participating in the program subject their parts to three complete stabilization cycles. The recommended manufacturing sequence for unplated parts made of 440C is: (1) Machine parts to within about 0.002 inch of finish dimension; (2) Heat treat (harden, quench, three heat cycles from cold stabilization temperature to tempering temperature); (3) Finish grind; (4) Bake 4 hours and; (5) Finish lap.

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[5] American Society for Metals, Metals Handbook, ed. Taylor Lyman (8th ed; Novelty, Ohio: American Society for Metals, 1960), Vol I, p 419.

Di-electric breakdown - The manufacture of acceptable solenoids has been a sizeable problem for two of the five firms holding contracts for solenoid operated selector valves. These solenoids are required to operate in an ambient temperature of 650°F. Each of the five companies selected Ceramitemp wire after a survey of the available wires for this environment. The Ceramitemp wire (made by Hi-Temp Wires, Inc.) will withstand continuous operation at 650°F; however, the ceramic-type insulation is brittle and tends to flake off if care is not exercised in the winding and subsequent handling of the solenoid. Some of the solenoids are terminated with the Ceramitemp wire brazed directly to the connector while others utilize a lead wire to join the solenoid and connector. One type of lead wire is teflon insulated with a silicon - fiberglass cover over the teflon. Di-electric breakdown has occurred on numerous solenoids used by two of the five firms while the others have had little or no trouble of this nature. One of the manufacturers experiencing repeated di-electric failures has attributed the failures to carelessness in handling the solenoids.

Effect of temperature on pressure setting - Operation of certain components over a wide temperature range will cause a slight change in their operating characteristics. Spring-loaded valves such as relief valves will display a slightly lower cracking pressure at 450°F than at 95°F. The coefficient of elasticity of Inconel X and 17-7 PH stainless steel from which the springs are made decreases as the temperature is increased over this range. In the pressure switch a bourdon tube displays the same characteristic. The pressure at which the electrical contacts open is approximately 50 psi lower at 450°F than at 95°F.

If the system demands that a valve open at a constant pressure over a wide temperature range, some sort of a compensator may be included in the valve. This usually consists of an aluminum part or other material which has a higher coefficient of thermal expansion than the adjacent steel parts and which is incorporated in such a way that the spring is compressed further at high temperature. Usually the system does not require that the valve open within so narrow a limit as to warrant compensators.

Valve instability - Instability has been a problem to a varying degree in the development of thermal relief valves, pressure relief valves, and priority valves. The rated flow to be handled by the thermal relief valve has been increased to 0.1 GPM as compared with 15 cc/min required of the valves qualified under specification MIL-V-5527A. This increased flow requirement created instability problems which had not existed in earlier designs. Some experimental work was necessary in order to determine the amount of damping required to overcome the problem. It is interesting to note that only one manufacturer, of the many submitting proposals for the thermal relief valve, foresaw an instability problem and included a spring-mass-damper analysis as part of the preliminary design. This manufacturer was not awarded a development contract because of objections in the design of the pressure setting adjustment. The background for such an analysis may be found in any elementrary text on mechanical vibrations. Such an analysis could be applied to any direct operating relief valve so that the valve viscous damper is designed to provide a damping factor ratio C/C_c between 0.5 and 1.0, where

C_c, critical damping factor, $2\sqrt{mK}$

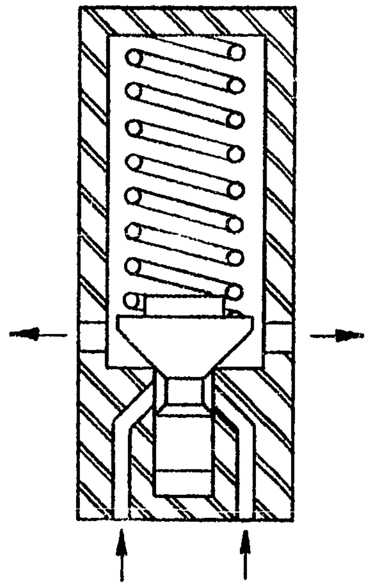
m, mass of poppet and damping piston

k, spring rate of spring

The pressure relief valves were of two types: (1) direct operating and, (2) pilot operated. These two valve types are schematically represented in Figure 2. Stability was achieved in the direct operated valve through the use of a damping piston. The clearance between the damping piston and the damping chamber was initially made as small as practical to produce a valve which was stable but sluggish. The clearance was then increased in small increments until a satisfactory compromise between response and stability was obtained. The pilot operated valve presented another set of problems. The pilot stage by itself functions just like a direct operating relief valve and is subject to instability if too high a flow rate is passed through the pilot stage. This can be overcome by restricting the amount of flow to the pilot stage. However, the location of the restriction within the main stage slider was found to be very critical. If located in a region of turbulent flow the valve will remain unstable. Therefore, the main slider was modified so that a projection containing the orifice extends into the less turbulent flow stream.

Two of the three priority valves tended to be unstable. One unit was very similar to the pilot operated relief valve discussed above. It was made stable by the addition of a flow limiter to the pilot stage.

DIRECT OPERATING RELIEF VALVE
WITH DAMPING PISTON



PILOT OPERATED RELIEF VALVE

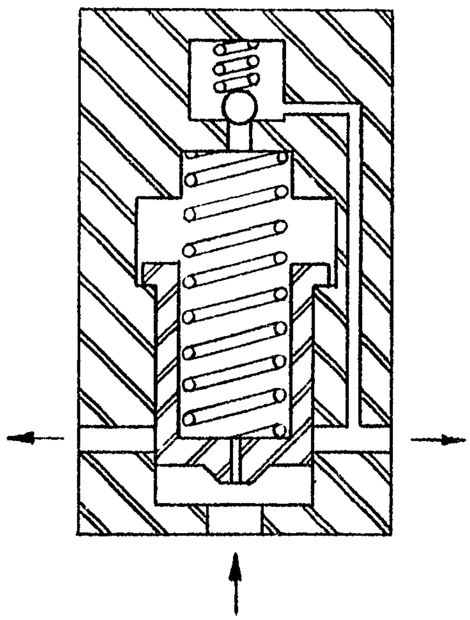
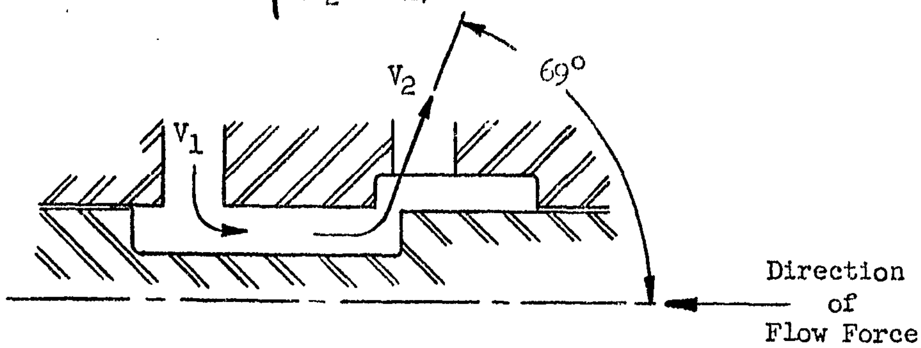


FIGURE 2
SCHEMATIC REPRESENTATION OF TWO
TYPES OF PRESSURE RELIEF
VALVES

Flow Forces - Axial forces on a valve spool are often created by the fluid flowing through the valve. This force can be calculated from the change in momentum of the fluid between inlet and outlet of the valve by the equation $F = Q\rho(V_2 - V_1)$.



In this equation Q and ρ are scalar quantities while F and $(V_2 - V_1)$ are vector quantities. From the equation it can be seen that the flow force will increase as the flow rate increases. Accordingly the 25 GPM valves experienced higher flow forces than the 4 or 12 GPM valves. This must be considered in the design of components such as pressure operated shut-off valves which must open and close within a narrow actuation pressure range, for flow forces may act so as to place the full open and closing pressures outside the allowed pressure range. A very thorough analysis of axial flow forces along valve spools and experimental work to support the analysis has been presented by Dr. Lee and Dr. Blackburn of Massachusetts Institute of Technology.[6] Flow forces can be minimized by several methods. The velocity of fluid flow can be reduced by providing larger flow area with resulting decrease in the flow force. Since $V_2 - V_1$ in the above equation represents a vector subtraction, the magnitude may be reduced by changing the angles at which the fluid enters and leaves the slider groove. Then in the case of four way valves two oppositely directly forces may be made to cancel each other.

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[6]S.Y. Lee and J. F. Blackburn, "Axial Forces on Control - Valve Pistons," Meteor Report No. 65, (Massachusetts: M.I.T., 1950)

Thermal shock - Tests on two of the four way, three position selector valves (one cartridge and one face mounted) have shown that it is possible to cause a malfunction of the valve by subjecting it to a thermal shock. A rapid warm up test is included in the qualification and the units will perform satisfactorily in this test. However, if fluid which is 100°F hotter than the valve is suddenly introduced,the valve spool will expand more rapidly than the valve body, and seizure will take place within a few cycles as alternate solenoids are energized. The valve will function normally at the higher temperature when the temperature stabilizes throughout the valve. An assembly with increased clearance was found to behave similarly. It was concluded that this type malfunction can not be eliminated by increased clearance and still maintain a reasonable leakage rate. The situation described is not peculiar to these particular valves. It should be typical of many sleeveless valves or of valves in which the sleeve is shrink fitted into the valve body. It is mentioned here only because the situation is one which the system designer should be aware of.

Orifice protection - Erratic performance of the 25 GPM relief valve was obtained during development testing. This was first thought to be the result of entrapped air being released from the fluid as it passed throught the 0.015 inch diameter orifice to the pilot stage. Air was accumulated between the slave poppet and pilot poppet which was difficult to bleed from the valve. Once this occurred, a very low inlet pressure was sufficient to move the slave poppet against the cushion of air so that rated flow was passed from inlet to outlet ports. How-

ever, further investigation showed that this erratic performance was caused by partial clogging of the screen which protects the orifice. When the screen was thoroughly cleaned the valve functioned properly regardless of the quantity of air trapped. The filter screen used was an absolute 20 micron rating which is a higher degree of filtration than required in this application. Specification MIL-H-5440 requires that all orifice holes smaller than 0.070 inch diameter in flow regulators and restrictors be protected by a filter element having a screened opening of 0.008 inch to 0.012 inch. Most valve manufacturers, being aware of this requirement, utilize a filter screen to protect the orifice in valves other than restrictors and flow regulators; however, they sometimes use a screen which does not conform to the above dimensions. The requirement for a screen with a 0.008 inch minimum opening should apply to such pilot operated valves as relief valves, priority valves, and solenoid operated selector valves. Too high a degree of filtration will encourage clogging and thereby defeat the purpose of the filter.

Filter assembly differential pressure indicators - The indicator in a filter assembly is used to sense the differential pressure between the upstream and downstream sides of the filter element. The indicator design is usually based upon pressure acting upon a piston until the force becomes great enough to overcome the preload in a spring - at which time a red indicator button "pops out." Most indicator designs for low temperature applications utilize elastomers as dynamic seals on the sensing piston. Qualification of a high temperature indicator utilizing reed seals as a dynamic seal was attempted on the 4 GPM filter. While this provided no initial leakage and a low leakage rate after

endurance cycling, the design could not be considered satisfactory because of external leakage. The indicators which were ultimately qualified in the 4, 12, and 25 GPM filters were magnetic types in which both the indicator button and the actuating piston are permanent magnets separated by a thin steel wall. No external dynamic seals are required. An internal dynamic seal is still needed on the sensing piston.

Filter washout - Much effort was spent in developing filter configurations for use within the restrictor valves. All orifices smaller than 0.07 inch in diameter must be filtered, and these filters repeatedly failed during the erosion test in which flow sufficient to maintain a 5,000 psi differential pressure is passed through the orifice. Several different types of wire cloth were used. An acceptable valve was finally created by including baffle pates to disburse the flow and reduce the velocity through each filter.

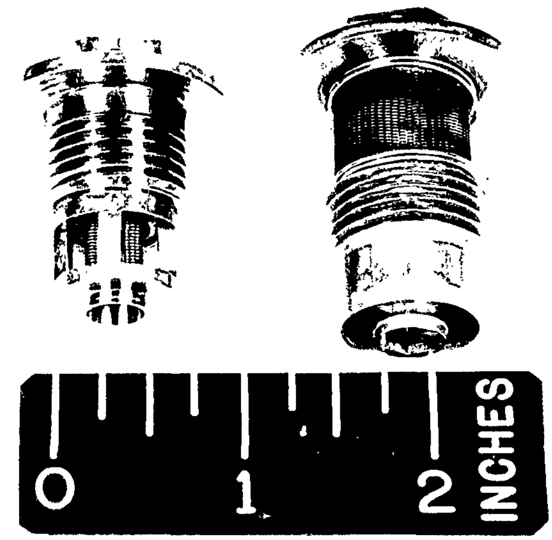
IV

CONCLUSIONS

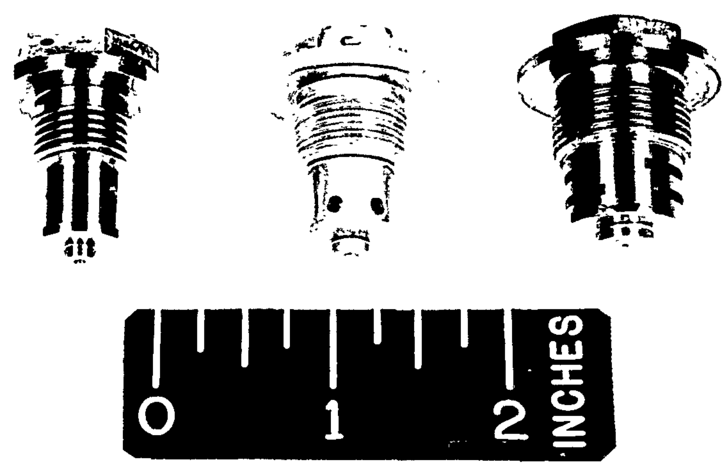
Figures 3 through 9 show photographs of the completed modular valves, the switch, and filter assemblies. Three units of each type shown have been produced for delivery to the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania, in partial fulfillment of the requirements of Contract NOas 59-6019-c. One of the three units has been subjected to the qualification tests specified in the applicable specification (see appendix). The other two units have been acceptance tested, and some have been subjected to random tests from qualification or to tests within packages. Table 4 shows the acceptance test effort for each of the units. The following documentation necessary to the establishment of a Qualified Products List has been forwarded to the Bureau of Naval Weapons, Navy Department, Washington 25, D.C.:

- 2 copies of each suggested MIL specification
- 2 copies of list of materials
- 1 reproducible drawing of component
- 2 copies of component drawing
- 2 copies of qualification test report
- 2 copies of each suggested MS standard page

Each of the manufacturers listed in Table 5 is considered to be eligible for inclusion in a Qualified Products List for Type III aircraft hydraulic components. In addition to these components the following

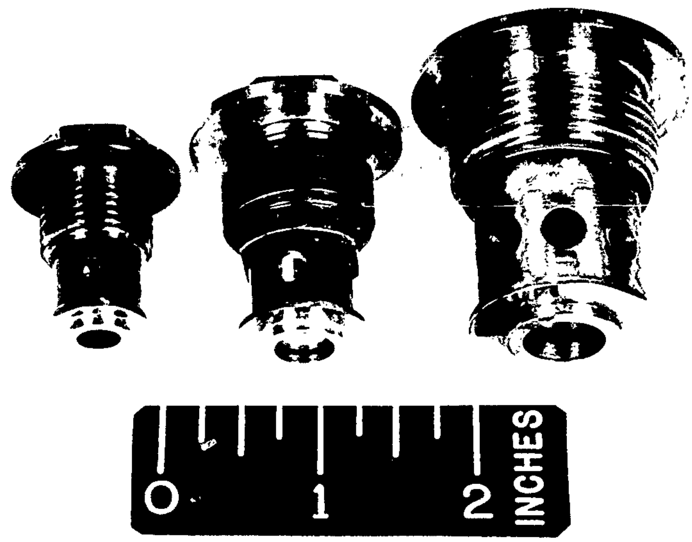


ONE WAY RESTRICTOR & TWO WAY RESTRICTOR

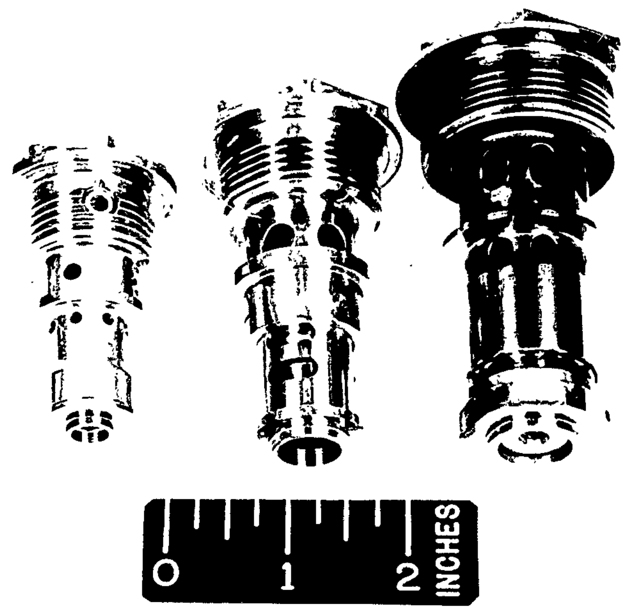


1500, 3000, & 4000 PSI SYSTEM THERMAL RELIEF VALVES

FIGURE 3
MODULAR VALVE ASSEMBLIES



4, 12, & 25 GPM CHECK VALVES



4, 12, & 25 GPM SHUTTLE VALVES

FIGURE 4
MODULAR VALVE ASSEMBLIES

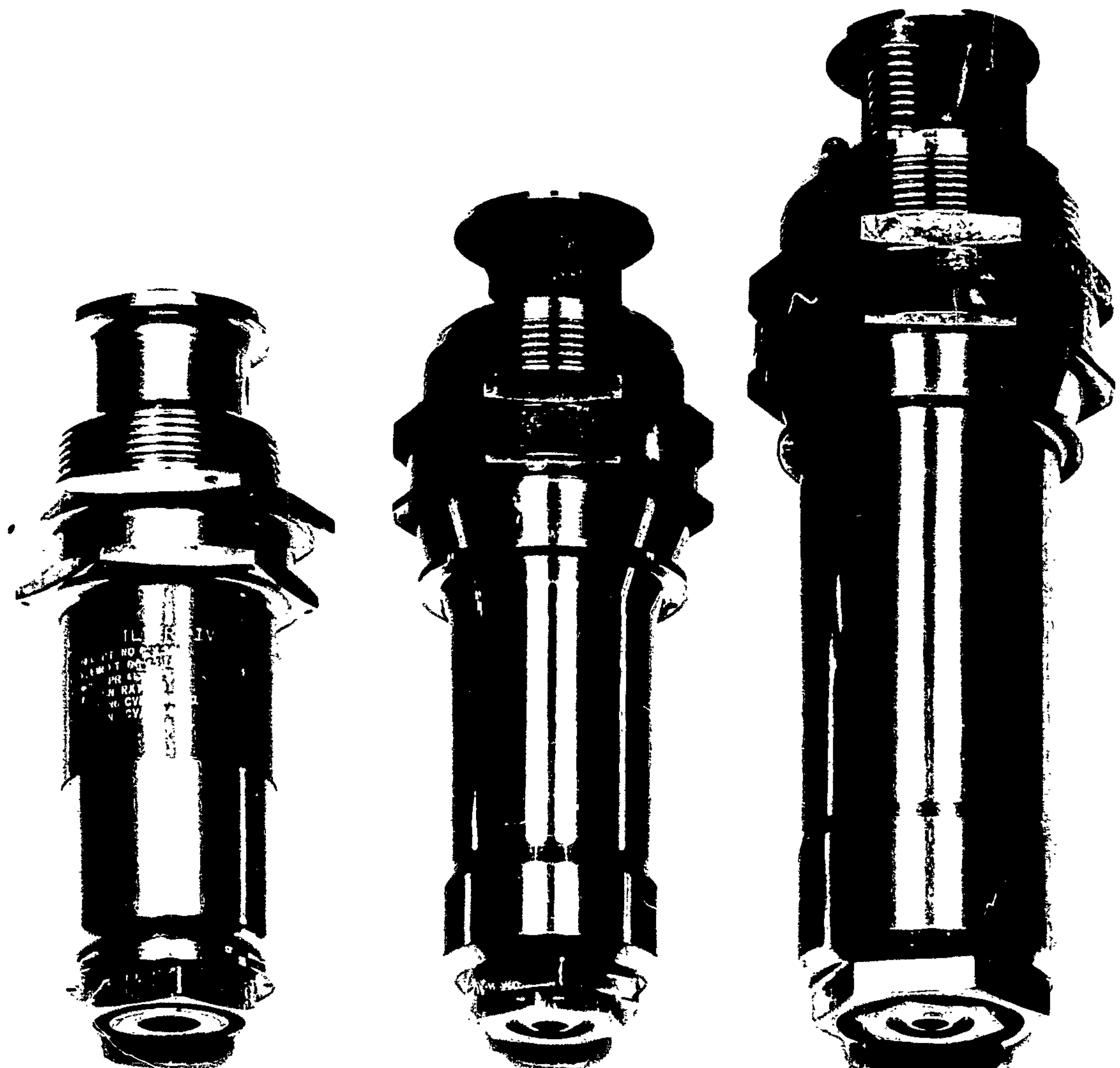
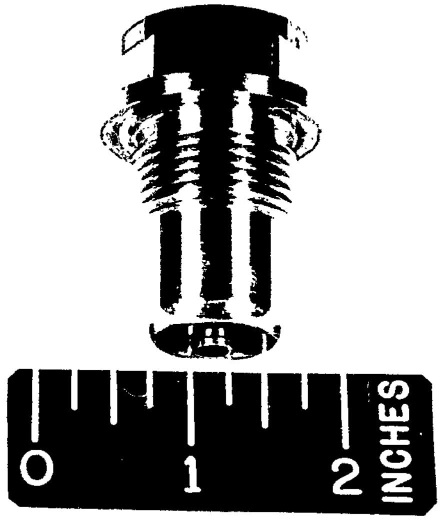
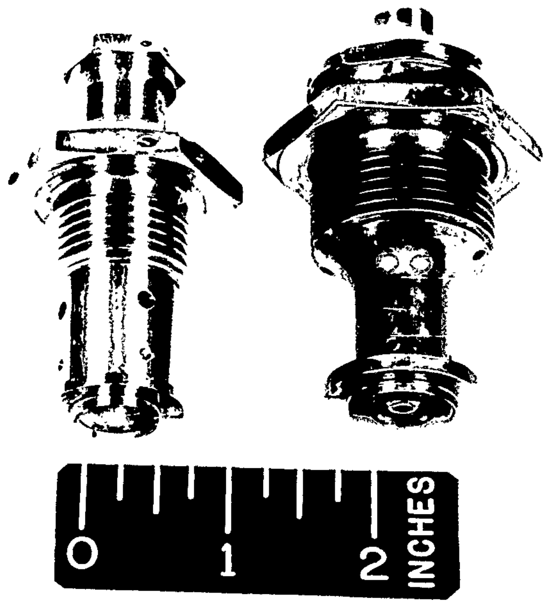


FIGURE 5
4, 12, & 25 GPM FILTER ASSEMBLIES

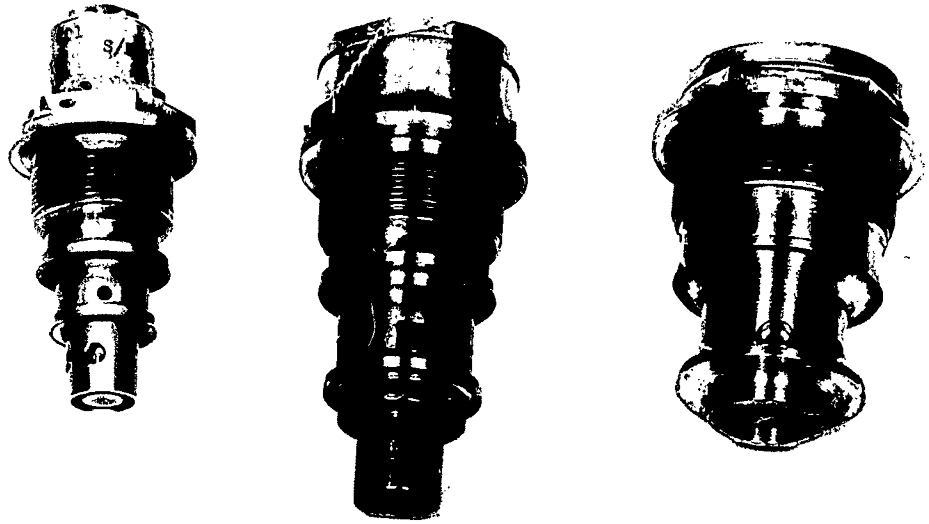


PRESSURE SWITCH

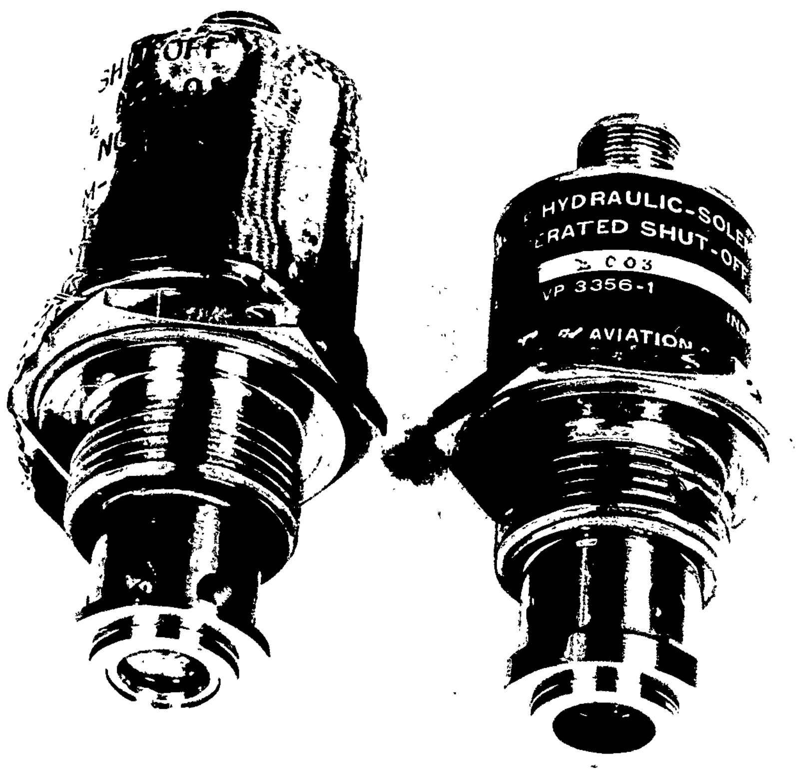


4 & 25 GPM RELIEF VALVES

FIGURE 6
MODULAR COMPONENT ASSEMBLIES

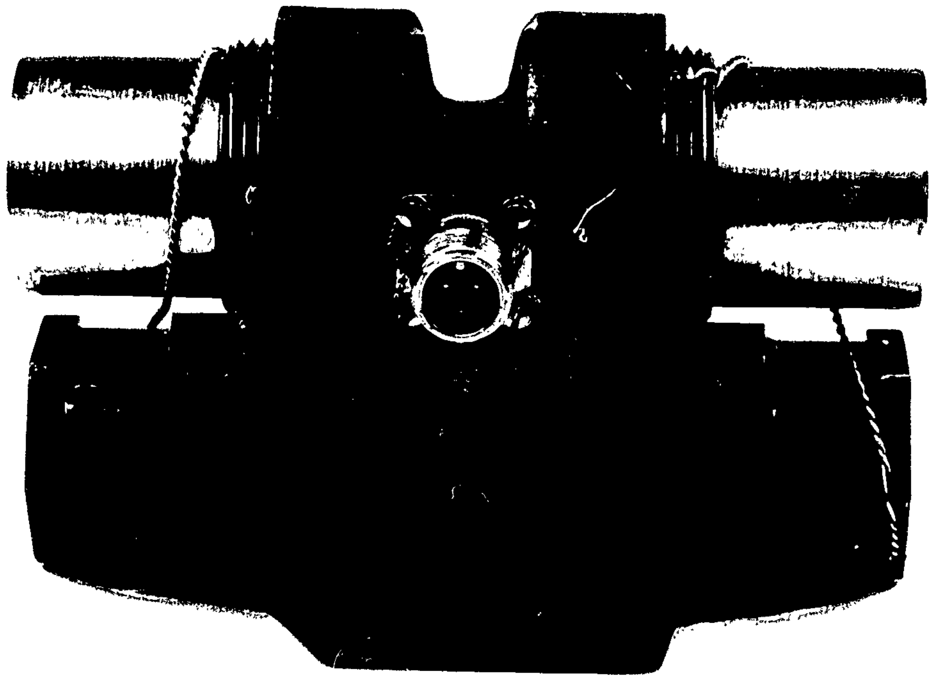


4, 12, AND 25 GPM PRIORITY VALVES

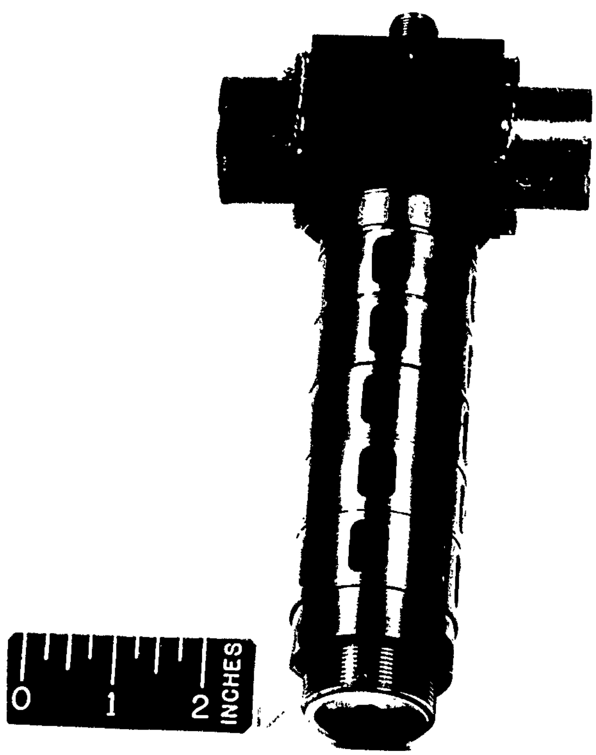


25 GPM SOLENOID OPERATED SHUT-OFF VALVES

FIGURE 7
MODULAR VALVE ASSEMBLIES

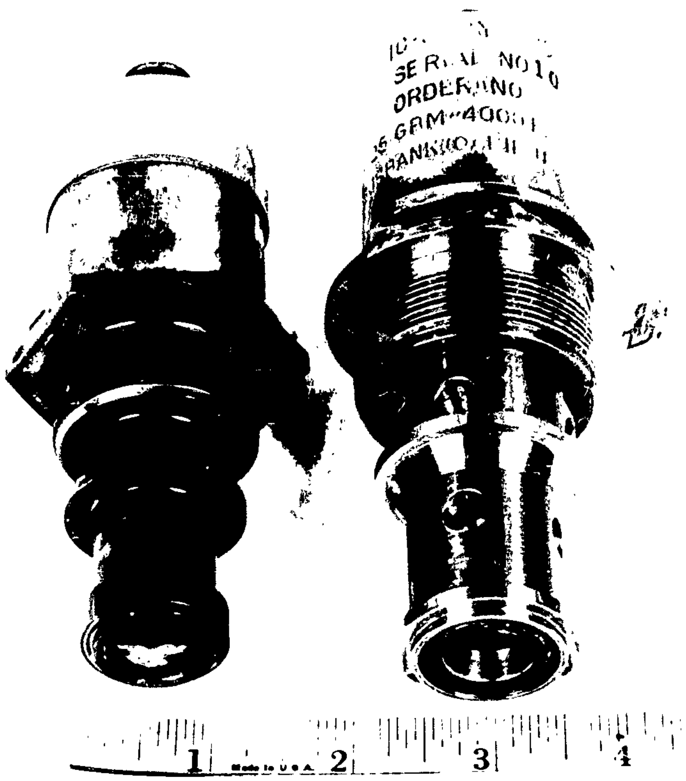


12 GPM
4 WAY, 3 POSITION SELECTOR VALVE
(FACE MOUNTED TYPE)

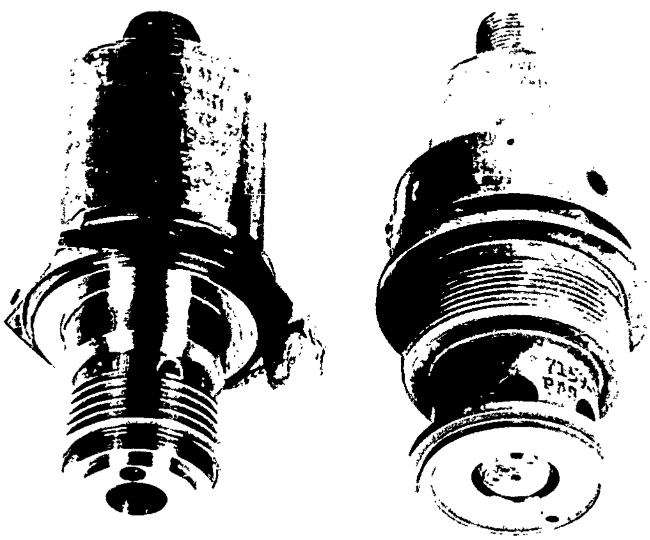


25 GPM
4 WAY, 3 POSITION SELECTOR VALVE
(CARTRIDGE TYPE)

FIGURE 8



4 AND 25 GPM SOLENOID OPERATED 3 WAY, 2 POSITION SELECTOR VALVES



12 AND 25 GPM SOLENOID OPERATED SEQUENCE VALVES

FIGURE 9
MODULAR VALVE ASSEMBLIES

TABLE 4

EVALUATION TESTS

Component	Times Test Conducted	Times Returned To Vendor	Final Configuration Acceptable	No. Of Parts Tested
1. Restrictor, 2 Way, Class B	1		Yes	1
2. " 1 Way, " A	1		Yes	1
3. Check Valve, Class A	1		Yes	1
4. " " " B	1		Yes	1
5. " " " C	3	1	Yes	3
6. Shuttle Valve, Class A	1	1	Yes	1
7. " " " B	1		Yes	1
8. " " " C	2	2	Yes	1
9. Pressure Switch	1		Yes	1
10. Thermal Relief Valve,Class A	2		Yes	1
11. " " " " B	2	1	Yes	1
12. " " " " C	1		Yes	1
13. Priority Valve, Class A	1	1	No	1
14. " " " B	2	1	Yes	2
15. " " " C	2	2	Yes	2
16. Pressure Relief Valve,Class A	1		Yes	1
17. " " " " C	3	2	Yes	3
18. Pres. Oper. Shut-Off V, Class A	3	2	No	3
19. " " " " B	3	1	No	1
20. " " " " C	0	0	-	0
21. Select.Val. 4W-3P, Class A	1	1	No	1
22. " " " " C	1		Yes	1
23. Filter, Class A	2	1	Yes	1
24. " " B	2		Yes	1
25. " " C	1		Yes	1
26. Sol. Oper. Seq. Valve, Class B				
27. " " " " " C	1		Yes	1
28. 3W-2P, Control Val, Class A	2	1	Yes	1
29. " " " " C				
30. " " " " C	1		Yes	1
31. Sol. Oper. Shut-Off V, Class C				
32. " " " " " C	1		Yes	1
33. 4W-3P, Control Valve, Class B	1		Yes	1

TABLE 5

RECOMMENDATIONS FOR QUALIFIED PRODUCTS LIST

Manufacturer	Component
Crescent Sargent Corporation	Check Valve - 4 GPM
Gar Precision Parts, Inc.	Check Valve - 12 GPM
Republic Manufacturing Company	Check Valve - 25 GPM
Ronson Hydraulic Units Corporation	One Way Restrictor
Ronson Hydraulic Units Corporation	Two Way Restrictor
Bendix-Pacific Division	Thermal Relief Valve (2100 to 3100 psi)
Fluid Regulators Corporation	Thermal Relief Valve (3100 to 4100 psi)
Altair, Inc.	Thermal Relief Valve (4100 to 5100 psi)
Consolidated Controls Corporation	Shuttle Valve - 4 GPM
Ronson Hydraulic Units	Shuttle Valve - 12 GPM
Langley Corporation	Shuttle Valve - 25 GPM
Rochester Manufacturing Company	Pressure Switch
Sargent Engineering Corporation	Priority Valve - 25 GPM
M. C. Manufacturing Company	Relief Valve - 4 GPM
Bendix - Pacific Division	2 Way, 2 Position Selector Valve - 25 GPM
Ronson Hydraulic Units Corporation	Solenoid Operated Sequence Valve - 25 GPM
Bendix - Pacific Division	4 Way, 3 Position Selector Valve - 25 GPM
Bendix - Filter Division	Filter - 4 GPM
Aircraft Porous Media	Filter - 12 GPM
Aircraft Porous Media	Filter - 25 GPM

units have completed qualification tests with some deficiency which does not meet the requirements of the applicable specification:

1. Three way, two position selector valve - (25 GPM) - Whittaker Controls

2. Three way, two position selector valve - (4 GPM) - Sargent Engineering

3. Four way, three position selector valve - (4 GPM) - Whittaker Controls

Items (1) and (2) above leaked excessively and experienced dielectric failure of the solenoid during the vibration test. The schedule for completion of Project Hydratoy does not allow time for fabrication of new valves and qualification of those units. Production valves could have these deficiencies corrected by closer control of the clearance in lap assemblies and by use of a solenoid wire which is less subject to failure than the ceramic insulated wire which was used on the prototype valves. In order that the three way valve specification be satisfied, the following qualification tests should be performed on a production valve in the order listed: (a) Leakage (paragraph 4.6.3), (b) Vibration (paragraph 4.6.12), and (c) Solenoid Current Drain (paragraph 4.6.7). Item (3) above also experienced dielectric failure in the solenoid. It requires additional testing of a redesigned solenoid to render it suitable for a qualified products list. Development problems discussed in Section III have delayed completion of the qualification tests on several valves. The following units are still undergoing tests and will be eligible for inclusion in the Qualified Products List if test results are satisfactory:

1. Relief Valve - 25 GPM - Benbow Manufacturing Co.
2. 2 Way, 2 Position Selector Valve - 25 GPM - HydroAire
3. 3 Way, 2 Position Selector Valve - 25 GPM - HydroAire
4. Solenoid Operated Sequence Valve - 12 GPM - HydroAire
5. 4 Way, 3 Position Selector Valve - 12 GPM - Ronson Hydraulic Units Corp.
6. Priority Valve - 4 GPM - Fluid Regulators Corporation

Experience in testing Type III components has led to the conclusion that 100% of the units received from the manufacturer must be subjected to acceptance tests. Many of the units received have not functioned properly even though they were fabricated in a model shop and should be expected to be of high quality. The high rejection rate may be attributed to the fact that the units are model shop parts and that standard check out procedures have not been established at the source of manufacture. Sampling procedure should not be inaugurated until a sufficient history of a design and the manufacturer of the component is accumulated to warrant testing by samples. While most of the solenoid operated selector valves were qualified with solenoids wound from a ceramic coated wire, this wire cannot be considered desirable for production valves. It can be made to work satisfactorily but only with an unreasonable degree of care in the winding of the coil. At the time the valves were designed a survey revealed that the ceramic coated wire was the only available wire which would withstand continuous operation at 650°F. Late in the program two manufacturers turned to an alternate wire known as Annaconda ML. This wire has a Dupon Herox film for insulation and

and the film adheres to the wire much better than the ceramic. CVC has not evaluated the wire sufficiently to say that it is without shortcomings, but certainly this or some other newly developed wire is needed to bring the reliability of the solenoids up to an acceptable level. Anodized aluminum wire may be used to approximately 750°F; however, the resistance is appreciably higher than copper. This sometimes requires that the solenoid be made larger in order to produce the same flux density as a copper wire wound coil. On the other hand the cross section of a ceramic insulated copper wire is composed largely of ceramic while the anodized aluminum wire has a relatively thin coating of aluminum oxide. For the same size cross section the anodized aluminum wire provides a larger diameter conductor which partially compensates for the increased resistance. None of the units tested in this program utilized anodized aluminum wire.

The components have been designed to provide the minimum weight and size which is consistent with the pressure drop requirements established for the units. Potential savings in space, weight, system complexity, maintenance, and fleet logistics may be realized through the use of the modular components. A detailed comparison of the packaged system with a conventional system may be found in Part III of this report.

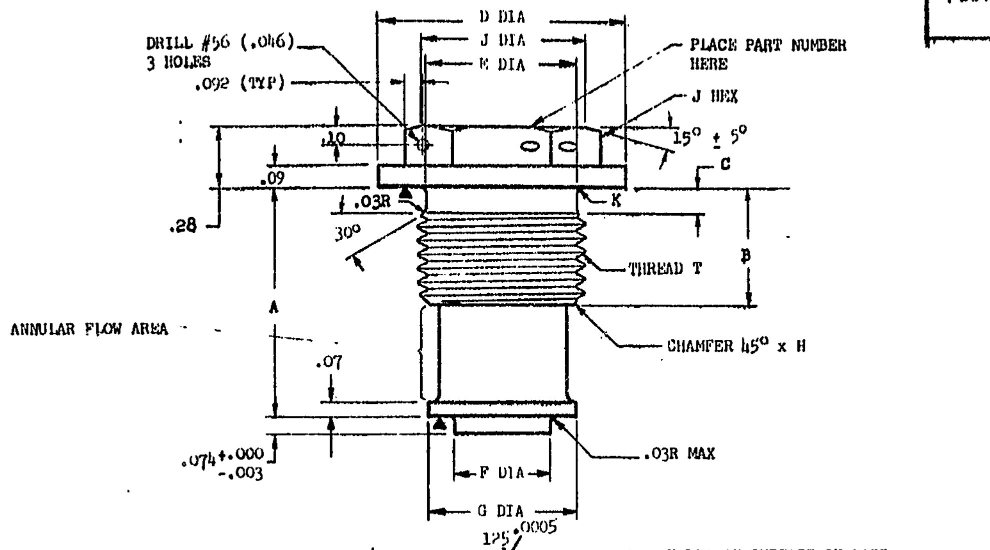
The components developed under this contract were selected because of their frequent use in aircraft hydraulic systems. Certainly there are other components which the system designer would desire to achieve the most benefits from the package concept. Cartridge type servo valves have recently found widespread use in Type II missile systems. Develop-

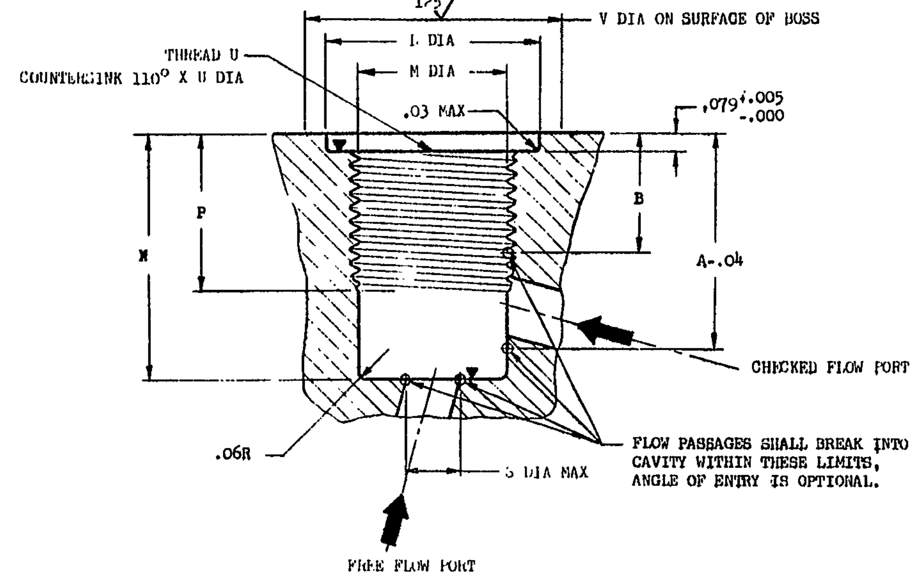
ment of a Type III servo valve in cartridge configuration would be a useful supplement to the group of valves already developed. A flow regulator is another component which is widely used in packaged Type II systems and should be developed for the Type III system. Then there are a number of pneumatic valves which should be developed and standardized in cartridge configurations for Type III systems.

APPENDIX I

Suggested MIL Specification for Check Valve
Suggested MS Standard for Check Valve

FED. SUP CLASS





PART NUMBER	THREAD "T"	A +.000 -.003	B	C	D DIA	E DIA +.000 -.005	F DIA +.000 -.001	G	H	J HEX	K	FLOW GPM	WEIGHT MAX.
MS- -1	3/4-16 UNF-3A	1.030	.53	.15	1.12	.659	.438	.66	.05	.75	.04	4	.14
MS- -2	1-12 UNF-3A	1.420	.67	.17	1.41	.899	.563	.87	.06	.88	.05	12	.25
MS- -3	1 3/8-12 UNF-3A	1.720	.67	.17	1.78	1.258	.750	1.24	.07	1.00	.05	25	

CAVITY FOR PART NUMBER	THREAD "U"	L DIA + .002 -.000	M DIA	N + .003 -.000	P + .03 -.00	S DIA MAX	V DIA MIN
MS- -1	3/4-16 UNF-3B	.968	.6823 +.0085 -.0000	1.109	.70	.297	1.16
MS- -2	1-12 UNF-3B	1.250	.9098 +.0100 -.0000	1.499	.90	.540	1.45
MS- -3	1 3/8-12 UNF3B	1.625	1.2848 +.0100 -.0000	1.799	.90	.720	1.82

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC CHECK** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

DETAIL REQUIREMENTS

TEMPERATURE LIMITS	-	+450°F FLUID AND +600°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE	-	OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI.
FLUID	-	SPECIFICATION MIL-H-8446.
SEALS	-	SPECIFICATION MIL-
LIFE	-	SEE SPECIFICATION MIL- FOR ENDURANCE.
PRESSURE DROP	-	75 PSI MAXIMUM AT RATED FLOW.

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16√ RHR. ALL OTHER SURFACES 125√ RHR.

TOLERANCES: THE SEALING SURFACES OF DIAMETERS "D" AND "G" SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THREAD "T" (AXIS) WITHIN .003 FIR. THE SEALING SURFACES OF DIAMETERS "K" AND "M" SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THREAD "U" (AXIS) WITHIN .003 FIR. SURFACE DEFINED BY "V" DIAMETER SHALL BE PERPENDICULAR TO THREAD "U" AXIS WITHIN .001 FIR.
LINEAR TOLERANCE: UNLESS OTHERWISE NOTED ±.01.
ANGULAR TOLERANCE: UNLESS OTHERWISE NOTED ±2°.
THIS VALVE INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- .
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE APPLICABLE COMPLETE MS PART NUMBER, THE WORDS "CHECK VALVE", THE RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON THE HEX AND/OR FLANGE SURFACES SUCH THAT MARKING IS VISIBLE WHEN THE VALVE IS INSTALLED.

REVISED

APPROVED

P.A. NAVY POWERS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC CHECK** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION

VALVE, AIRCRAFT HYDRAULIC CHECK

1. SCOPE

1.1 Scope. This specification covers cartridge-type modular hydraulic check valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification. Check valves shall be of the following classes.

Class 1 - 0 to 4 gallons per minute capacity

Class 2 - 0 to 12 gallons per minute capacity

Class 3 - 0 to 25 gallons per minute capacity

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification:

Specifications

Federal
PP-T-60 Tape, Pressure Sensitive Adhesive, Waterproof

Military
MIL-B-121 Barrier Material, Greaseproofed, Flexible, Waterproofed
MIL-I-6866 Inspection, Penetrant Method of
MIL-I-6868 Inspection Process, Magnetic Particle
MIL-H-6875 Heat Treatment of Steels (Aircraft Practice) Process for
MIL-S-7742 Screw Threads, Standard, Aeronautical
MIL-M-7911 Marking, Identification of Aeronautical Equipment, Assemblies and Part
MIL-H-8446 Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891 Hydraulic Systems, Type III, Design Installation, Tests and Data Requirements, Aircraft, General Specification for
MIL-D-70327 Drawings, Engineering and Associated Lists

Standards

MIL-STD-10 Surface Roughness, Waviness and Lay
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-143 Specifications and Standards, Use of
MS-33540 Safety Wiring - General Practices for
MS-20995 Wire - Lock

Drawings

MS Check Valve.- Modular Envelope for

2.2 Other publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in the order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification.- The check valve furnished under this specification shall be a product whhch has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes.- Materials and processes used in the manufacture of these valves shall conform to the following requirements and to applicable specifications as defined in Section 2.

3.2.1 Metals.- Metals shall be of a corrosion resisting type or shall be adequately protected to resist corrosion during the normal service life of the valve. Copper, aluminum and magnesium alloys shall be used only with the approval of the procuring activity.

3.2.2 Sub-zero stabilization of steel.- Close-fitting, sliding steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts. Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts.- Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the

drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the contractor's drawings.

3.4 Design and construction

3.4.1 Envelope.- The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification and applicable drawings.

3.4.2 Hydraulic fluid.- The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range.- The valves shall be designed to meet the functional and operational requirements of this specification throughout a range of -65°F to 450°F fluid temperature and -65°F to 650°F ambient temperature.

3.4.4 Threads.- Only class 3 threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals.- Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with Standard Drawing MS-33540 and MS-20995.

3.4.7 Retainer rings.- Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart of jamming of the valve.

3.4.8 Structural Strength.- The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight.- The weight shall be kept to a minimum consistent with good design, and shall be as specified on the applicable drawing.

3.4.10 Mounting position.- The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control.- The valves shall be designed to pass rated flow per 1.2 from inlet port to outlet. Flow shall be checked or blocked from outlet to inlet ports.

3.4.12 Surface roughness.- Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's Parts.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification.- Each valve shall have the identifying markings placed on the hex head or the flange so that the identification can be read when the

valve is installed in a manifold cavity. Each valve shall be permanently and legibly marked with the following information, per MIL-M-7911.

Valve, check
MS No.
Manufacturer's part No.
Manufacturer's Name or Trademark

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contaminants. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical Defect Inspection.- All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated pressure.- The valves shall be designed to operate in a hydraulic system having a rated pressure of 4,000 psi when tested per 4.6.9.

3.8.2 Operating pressure.- The valves shall be designed to insure satisfactory operation and service life throughout the operating range from 0 to 4,000 psi at

rated flows per 1.2, when tested per 4.6.9. The valves shall be capable of operation at 6,000 psi.

3.8.3 Proof pressure.- When 6,000 psi is applied to the valves per 4.6.2, there shall be no evidence of permanent set, failure, external leakage or other damage.

3.8.4 Burst pressure.- When 10,000 psi is applied to the valves per 4.6.11, no rupture of internal or external parts shall be evident. The valves shall not burst at any pressure below 10,000 psi.

3.8.5 Surge flow.- When the valves are subjected to 2,500 cycles of surge flow at 4,000 psi per 4.6.3, there shall be no evidence of damage to springs, poppets, or any other parts that would limit the service life of the valves.

3.8.6 Leakage.- When the pressures of Table I are applied to the valves, there shall be no evidence of external leakage and internal leakage shall not exceed the values of Table I, when tested per 4.6.4.

TABLE I
MAXIMUM ALLOWABLE INTERNAL LEAKAGE

PRESSURE psi	RATE cc/hr
5	8
1500	6
3000	4
4000	2

3.8.7 Pressure drop.- The pressure drop of the valves shall not exceed 25 psi for rated flow, as specified per 1.2, when tested per 4.6.5.

3.8.8 Operation checking time.- The valves checking time

shall not exceed 1.5 seconds, when tested per 4.6.6.

3.8.9 Cracking pressure.- Cracking pressure shall be that pressure which will produce a flow of 0.1 cc (approximately 2 drops) per minute during increasing

pressure. The valves cracking pressure shall not be less than 2 pounds per square inch nor greater than 8 pounds per square inch, when tested per 4.6.7.

3.8.10 Extreme Temperature.- The valves shall meet the requirements of paragraphs 3.8.6, 3.8.8, and 3.8.9 at stabilized temperatures of -65°F and 450°F, when tested per 4.6.8.

3.8.11 Endurance.- When the valves have been subjected to 50,000 cycles of operation per 4.6.9, they shall meet the internal leakage requirements specified in paragraph 3.8.6.

3.8.12 Vibration.- The valves shall be capable of withstanding vibrations from 5 to 2,000 cps with an amplitude of 0.04 inch (0.08 inch total excursion), or 15 "g"s whichever is limiting, along the three mutually perpendicular axes, when tested per 4.6.10.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.- The manufacturer is responsible for the performance of all acceptance tests prior to submission for Government inspection and acceptance. Unless otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests.- The inspection and testing of check valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of check valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Tests.- The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2.

(c) Surge flow per 4.6.3.

(d) Leakage per 4.6.4.

(e) Pressure drop per 4.6.5.

(f) Operation checking time per 4.6.6.

(g) Cracking pressure per 4.6.7.

(h) Extreme temperature performance per 4.6.8.

(i) Endurance per 4.6.9.

(j) Vibration per 4.6.10.

(k) Burst pressure per 4.6.11.

4.4 Acceptance tests.- Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance.

Each check valve shall be subjected to the following tests:

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2.

(c) Leakage per 4.6.4.

4.5 Test conditions

4.5.1 Test fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination.- Standard fine air cleaner test dust or approved contaminate mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of particle	Percent by weight of total
0 to 5 micron	39±2
5 to 10 micron	18±3
10 to 20 micron	16±3
20 to 40 micron	18±3
over 40 micron	9±3

4.5.4 Filtration.- The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity and which is acceptable to the procuring agency.

4.5.5.2 Acceptance test housing - The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test methods

4.6.1 Examination of product.- Each valve shall be carefully examined to determine conformance with the requirements of this specification for workmanship, marking, conformance to applicable drawings, or for any visible defects. Each valve shall be examined by probing the poppet in the free flow direction to assure that the check valve spring has been installed. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Proof pressure.- Pressure shall be applied to the check flow port at a rate not exceeding 25,000 psi per minute until 6,000 psi is reached. This proof pressure shall be held for at least two minutes, and there shall be no evidence of external leakage, permanent set or other damage. The check valve shall be filled with test fluid and stabilized at 450±15°F for qualification test only. For acceptance tests, proof pressure shall be conducted at 95±15°F for two minutes.

4.6.3 Surge flow.- The set-up for this test shall be as shown in Figure 1. The air precharge pressure for the accumulator shall be 1300±50 psi and the hydraulic test pressure for each check valve shall be 4,000 psi. The directional control valve shall be operated in the following sequence for 2,500 complete cycles. The following four point sequence shall constitute one cycle:

(a) The directional control valve handle shall be in a neutral position to permit build-up of 4,000 psi in the accumulator.

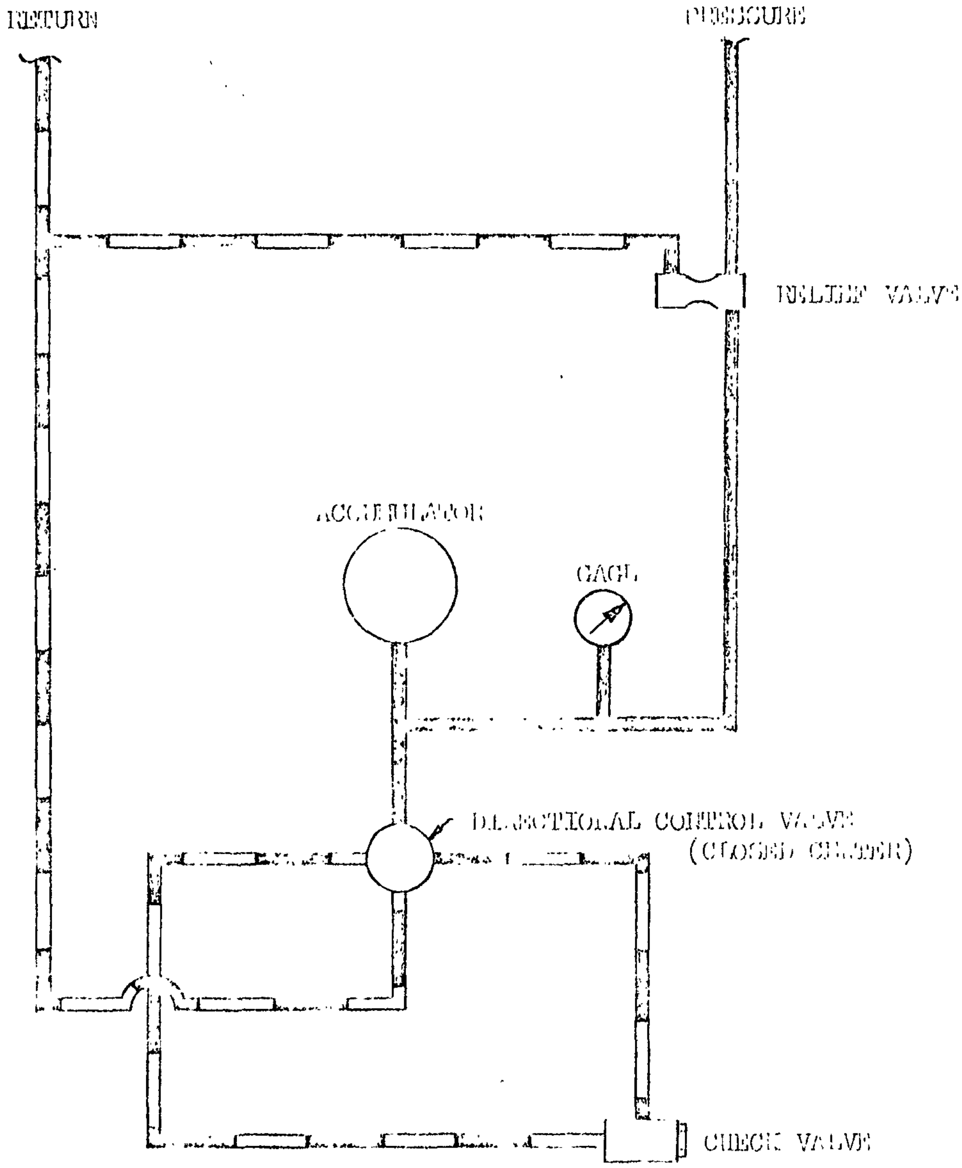


Figure 1

TYPICAL SETUP FOR SURGE FLOW TEST

(b) The directional control valve handle shall be quickly actuated to permit flow through the check valve in the free flow direction. The control valve handle shall remain in this position until the hydraulic pressure drops to a value less than the air precharge in the accumulator.

(c) The valve handle shall be returned to the neutral position to permit the build-up of 4,000 psi hydraulic pressure.

(d) The directional control valve shall be quickly actuated to permit flow to the check valve in the checked flow direction. The control valve handle shall remain in this position for at least 3 seconds and then returned to the neutral position.

Damage to springs, poppets, or any of the other parts shall be cause for rejection. Upon completion of this test, the check valves shall be subjected to the qualification test for leakage and the requirements thereof shall be satisfied.

4.6.4 Leakage.-

4.6.4.1 Qualification test for leakage.- This test shall be performed twice; once with the valve held in a horizontal position and once with the valve held in a vertical position so that the force of gravity acts opposite to the checking action. The valve shall be tested for leakage by applying pressures listed in Table I for a period of 32 minutes. The leakage measurement period shall begin two minutes after application of the required pressure. The fluid and valve temperature shall be 95±15°F for this test. All pressures shall be applied in the direction of checked flow, and the valve poppet shall be unseated between pressure applications. The rate of internal leakage shall not exceed the amount given in Table I. There shall be no external leakage.

4.6.4.2 Acceptance test for leakage.- This test shall be performed with the valve held in the vertical position so that the force of gravity acts opposite to the checking action. Pressures of 5 psi and 4,000 psi shall each be applied

in the reverse flow direction for a period of 5 minutes. The valve poppet shall be unseated between each pressure application. In each case the leakage measurement period shall consist of the last 3 minutes of the 5 minute period. The rate of internal leakage shall not exceed the values specified in Table I. There shall be no external leakage during this test. The valve and fluid temperature shall be 95±15°F for this test.

4.6.5 Pressure drop.- Pressure drop through the valve shall be determined at a flow equal to the rated flow as specified in 1.2. The pressure drop for the valve shall be determined as the difference between the pressure drop for the valve installed in a test housing and the pressure drop of the test housing with an end cap installed in place of the valve. The pressure drop of the check valve shall not exceed 25 psi for rated flow at a temperature of 95±15°F.

4.6.6 Operation checking time.- The poppet shall be mechanically actuated to its full open position against a static pressure of 5 pounds per square inch maximum. The valve shall then be allowed to check before the fluid pressure falls below one pound per square inch. The checking time shall be observed and shall not exceed 1.5 seconds.

4.6.7 Cracking pressure.- Gradually increasing pressure shall be applied to the valve inlet. Cracking pressure shall be observed and shall not be less than 2 pounds per square inch nor greater than 8 pounds per square inch. Cracking pressure is defined as that pressure which will produce a flow of 0.1cc (2 drops) per minute upon increasing pressure.

4.6.8 Extreme temperature performance

4.6.8.1 Low temperature performance.- The valve and fluid shall be soaked at -65°F for a minimum of 8 hours. After this soak period, the valve poppet shall be actuated mechanically at least two times. After each actuation the

tests of 4.6.4.2, 4.6.6, and 4.6.7 shall be performed and satisfied.

4.6.8.2 High temperature performance.- The temperature of the valve and fluid shall be stabilized at 450±15°F. The valve poppet shall be actuated mechanically at least two times. After each actuation the tests of 4.6.4.2, 4.6.6, and 4.6.7 shall be performed and satisfied.

4.6.9 Endurance.- The valve shall be subjected to 50,000 cycles of operation at a rate of 17-20 cycles per minute. Each cycle shall consist of passing rated flow through the valve in the free flow direction, followed by application of 5,000 to 6,000 psi surge pressure in the direction of checked flow. This endurance test shall be conducted while the valve undergoes the time-temperature spectrum as shown in Figure 2. Each spectrum should take approximately 6 1/2 hours to complete and should be made up of approximately 7,143 cycles. The first, fourth, and seventh spectrum shall begin at -65°F after the set-up has soaked at -65°F for at least 8 hours. The spectrum shall begin at 95±15°F on the second, third, fifth, and sixth spectrums. A typical test set-up for endurance cycling is indicated in Figure 3. After completion of endurance cycling, the fluid shall be stabilized at 95±15°F and tested for leakage per 4.6.4.2. Leakage shall not exceed the values shown in Table I.

4.6.10 Vibration.- With the fluid temperature maintained at 95±15°F, the valve shall be cycled by alternately imposing rated flow in the free flow direction and then applying 4,000 psi in the checked direction at the rate of 15±5 cycles per minute. While the valve is being cycled in this manner it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2,000 cycles per second in 30 minutes. The amplitude shall be 0.04 inches (0.08 inch total excursion) or 15 G's, whichever is limiting. This test shall be repeated, and the frequency of any and

all resonant points (natural frequencies) shall be noted. Vibrate the valve for 90 minutes at the most severe resonant frequency noted above at 0.08 inch total excursion or 15 G's, whichever is less severe. If no resonant frequency is found, the valve shall be vibrated at 500 cps for 90 minutes. The above procedure shall be repeated with the direction of vibration changed 90° horizontally and again with the direction of vibration changed to vertical. After completion of the vibration test the valve shall be tested per 4.6.4.2 and shall be within the limits specified.

4.6.11 Burst pressure.- With the free flow port plugged, pressure shall be applied to the check flow port at a rate not to exceed 25,000 psi per minute until 10,000 psi is reached. This pressure shall be held for two minutes without rupture of internal or external parts. This test shall be repeated with the check flow port plugged and pressure applied to the free flow port. The fluid temperature shall be $95 \pm 15^{\circ}F$ for this test. The valve shall be removed from the test manifold and visually inspected for any mechanical failures.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging.- Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped in grade A greaseproof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments.- Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document
Name of part
MS Part No.
Month and year of manufacture
Class or size

NOTES:

1. Rate of temperature rise or decay may vary within the shaded areas shown.
2. Approximately six and one half hours of endurance cycling are to be run in one day.
3. The ambient temperature shall be maintained between 450 - 650°F during the time from the 2nd hour through 5 1/2 hours of the spectrum shown.

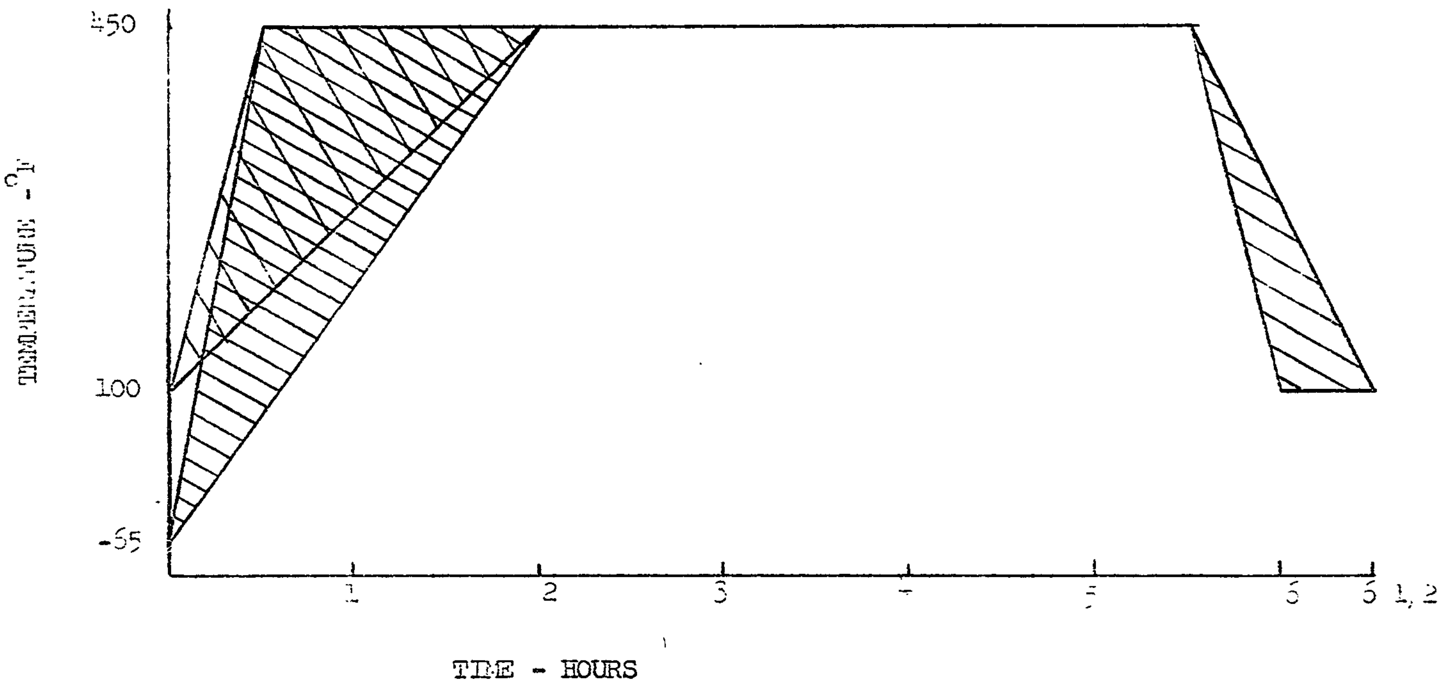


FIGURE 2

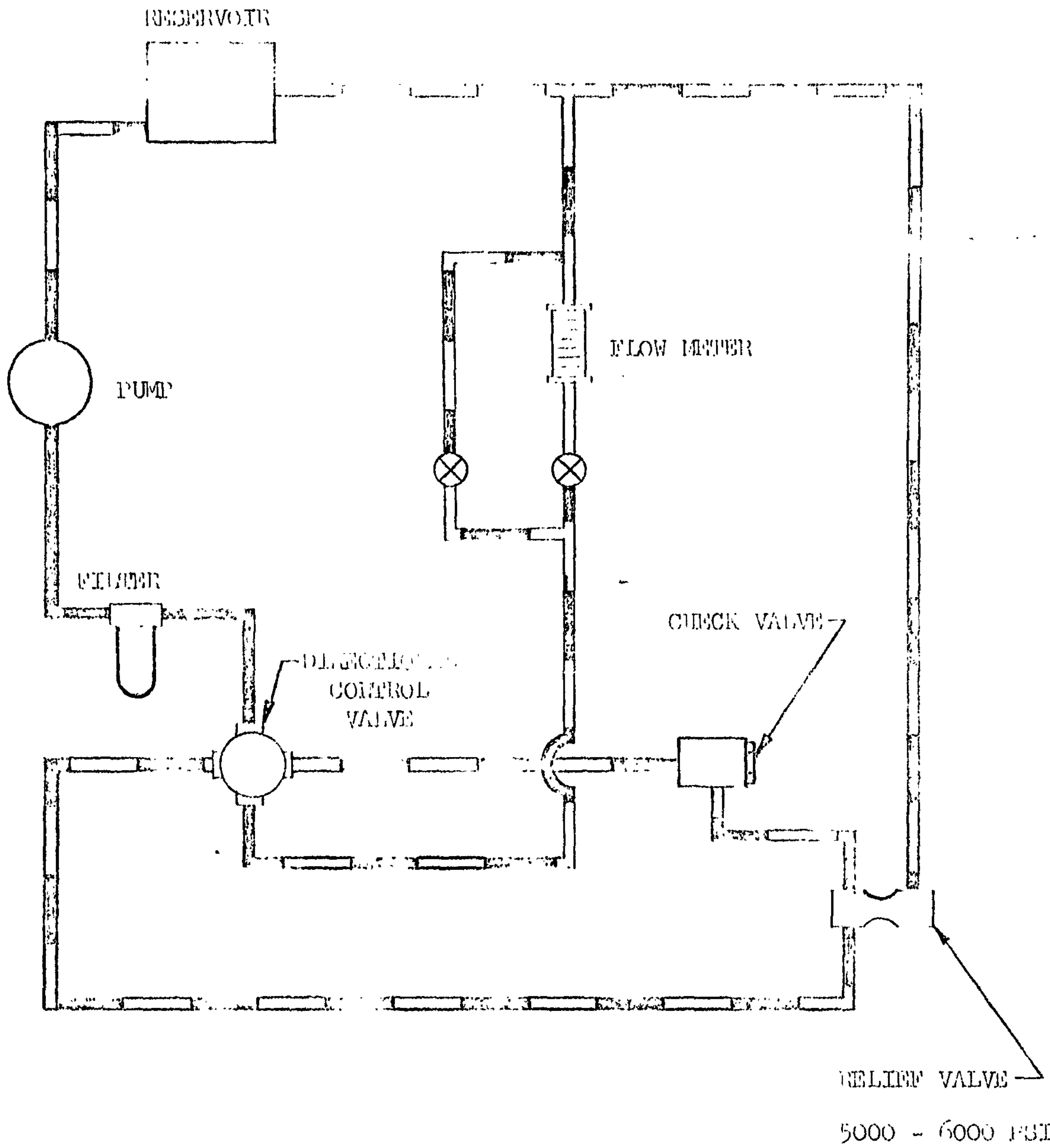


FIGURE 3
TYPICAL SETUP FOR ENDURANCE TEST

6. NOTES

6.1 Intended use.- The check valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specifications MIL-H-8891, and operating with hydraulic fluid conforming to Specification MIL-H-8446 at pressures which do not exceed 4,000 psi. The check valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering data.- Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number

(c) Class

(d) Federal stock number

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U.S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a defintely

related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

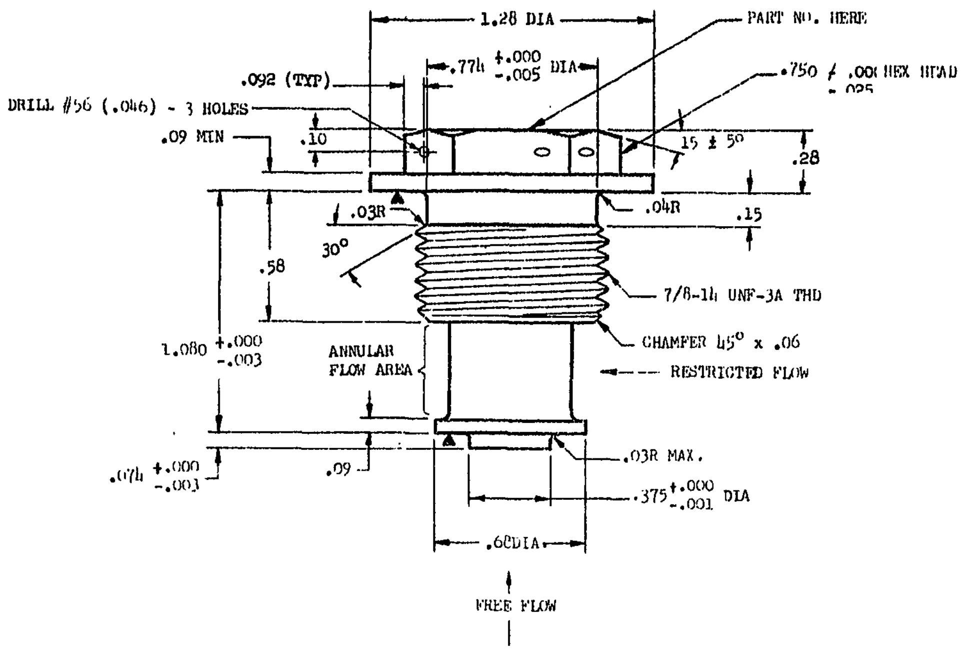
Preparing activity:

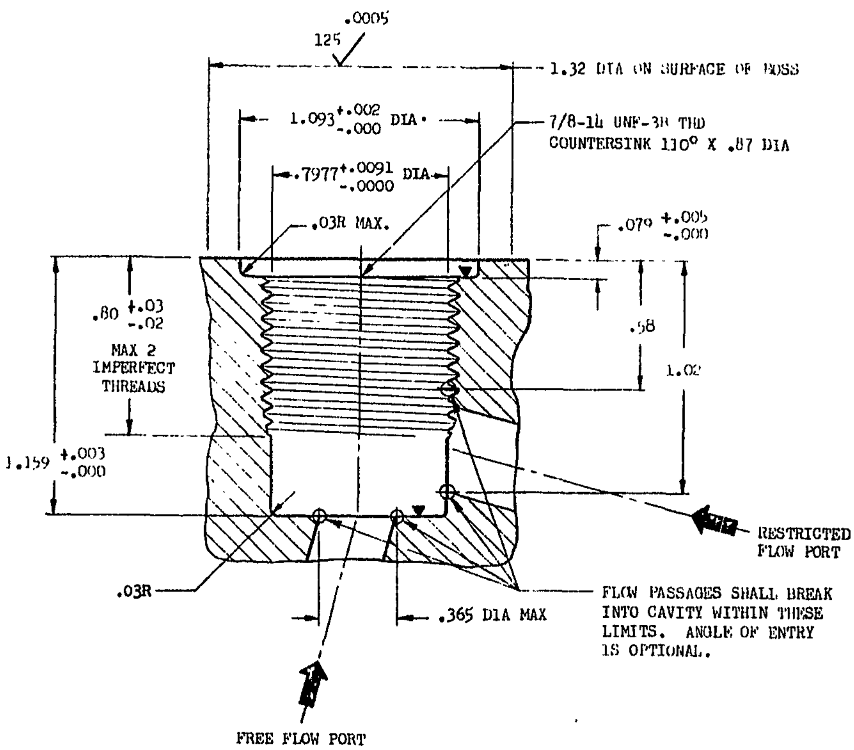
Navy - Bureau of Naval Weapons

APPENDIX II

Suggested MIL Specification for Restrictor
Suggested MS Standard For One Way Restrictor
Suggested MS Standard For Two Way Restrictor

FED. SUP CLASS





REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC RESTRICTOR** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

FED. SUP CLASS

DASH NUMBERS

DASH NUMBER	DASH NUMBER	DASH NUMBER
1	12	32
2	14	36
3	16	40
4	18	
5	20	
6	23	
8	26	
10	29	

DETAIL REQUIREMENTS

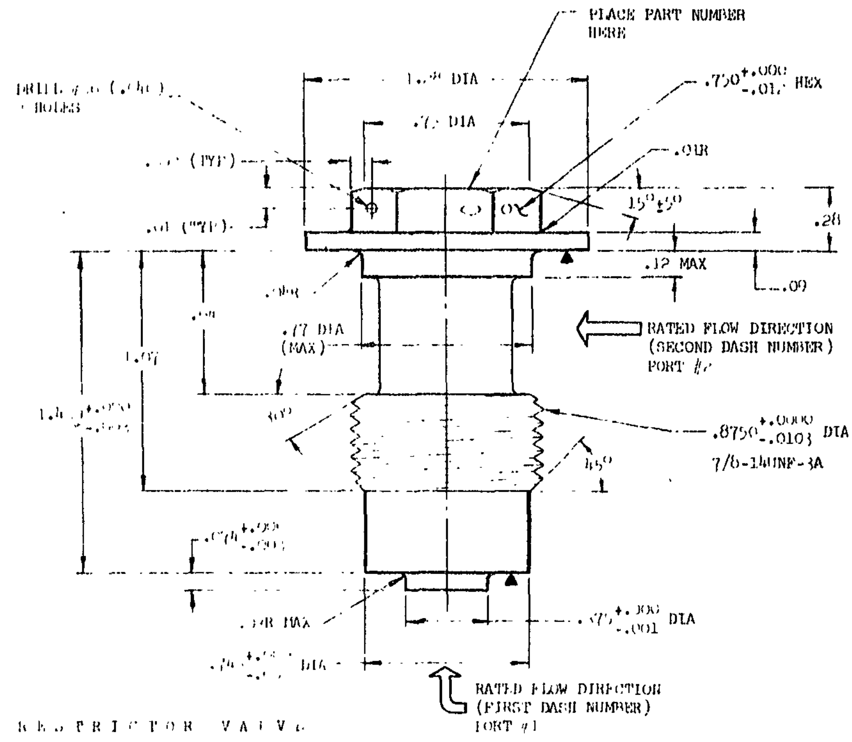
TEMPERATURE LIMITS - +450°F FLUID AND +650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE - OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI
FLUID - SPECIFICATION MIL-H-8446
SEALS - SPECIFICATION MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE
PRESSURE DROP - 2000 PSI AT RATED FLOW IN RESTRICTED FLOW DIRECTION; 25 PSI MAXIMUM IN FREE FLOW DIRECTION

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16/ RHR OR LESS. ALL OTHER SURFACES SHALL BE 125/ RHR MAXIMUM UNLESS OTHERWISE NOTED.
TOLERANCES: THE TWO SEALING SURFACES ON THE VALVE SHALL BE PARALLEL WITHIN .002 FIR AND PERPENDICULAR TO AXIS OF VALVE THREAD WITHIN .003 FIR. THE TWO SEALING SURFACES OF THE CAVITY SHALL BE PARALLEL WITHIN .002 AND PERPENDICULAR TO THE AXIS OF THE CAVITY THREAD WITHIN .003 FIR.
LINEAR TOLERANCE: ±.01 INCH UNLESS OTHERWISE NOTED.
ANGULAR TOLERANCE: ±2° UNLESS OTHERWISE NOTED.
THIS VALVE IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- . DASH NUMBER INDICATES FLOW RATE THROUGH RESTRICTOR VALVE, IN RESTRICTED DIRECTION, IN TENTHS OF A GALLON PER MINUTE AT 2000 PSI DIFFERENTIAL PRESSURE.
SEAL SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE MS PART NUMBER, THE WORD "RESTRICTOR", THE MANUFACTURER'S NAME OR TRADEMARK AND THE MANUFACTURER'S PART NUMBER SHALL BE PERMANENTLY MARKED ON THE HEX AND/OR FLANGE SURFACES SUCH THAT THE MARKING IS VISIBLE WHEN THE VALVE IS INSTALLED.

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC RESTRICTOR** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2



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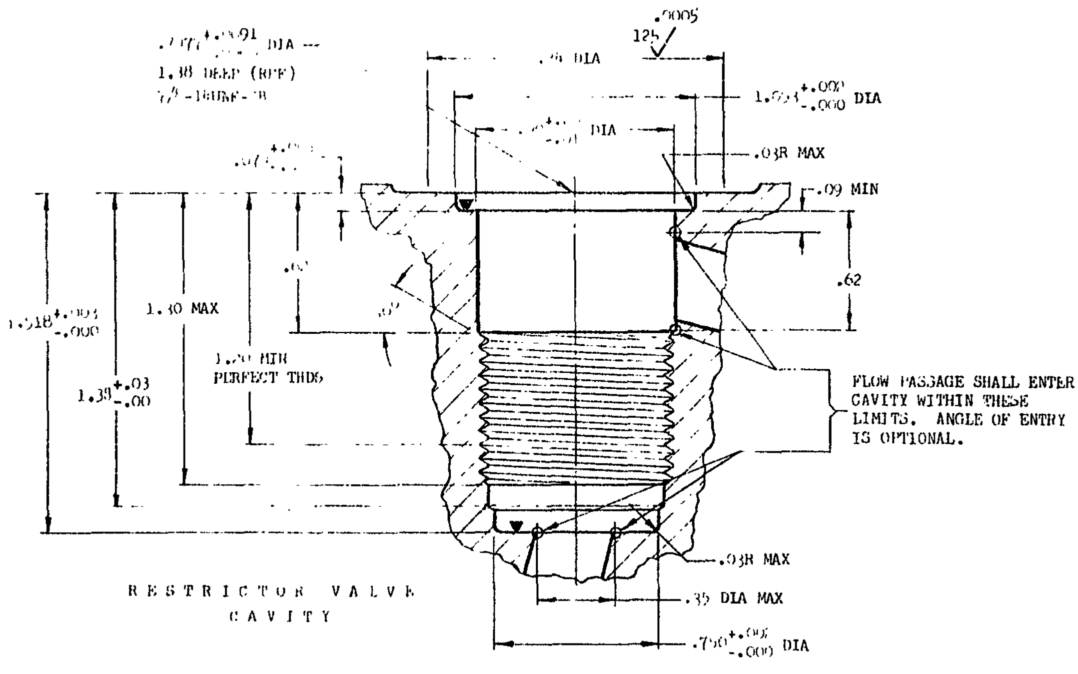


R E S T R I C T O R   V A L V E
C A V I T Y

FED. SUP CLASS

REVISED

APPROVED

P.A. NAVY LOWERS

Other Cost

TITLE **VALVE, MODULAR HYDRAULIC TWO-WAY RESTRICTOR**

4,000 PSI, TYPE III SYSTEM

MILITARY STANDARD

MS

PROCUREMENT SPECIFICATION MIL-

SUPERSEDES:

SHEET 1 OF 2

FED. SUP CLASS

DASH NUMBERS

DASH NUMBER	DASH NUMBER	DASH NUMBER
1	12	32
2	14	36
3	16	40
4	18	50
5	20	65
6	23	80
8	26	100
10	29	120

TEMPERATURE LIMITS - +450°F FLUID AND +450°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE - OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI
FLUID - SPECIFICATION MIL-H-8446
SEALS - SPECIFICATION MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE
PRESSURE DROP - 2000 PSI AT RATED FLOW IN EITHER FLOW DIRECTION

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16√ RHR OR LESS. ALL OTHER SURFACES SHALL BE 125√ RHR MAXIMUM UNLESS OTHERWISE NOTED.
TOLERANCES: THE TWO SEALING SURFACES ON THE VALVE SHALL BE PARALLEL WITHIN .002 FIR AND PERPENDICULAR TO AXIS OF VALVE THREAD WITHIN .003 FIR. THE TWO SEALING SURFACES OF THE CAVITY SHALL BE PARALLEL WITHIN .002 AND PERPENDICULAR TO THE AXIS OF THE CAVITY THREAD WITHIN .003 FIR.
LINEAR TOLERANCE: ±.01 INCH UNLESS OTHERWISE NOTED.
ANGULAR TOLERANCE: ±2° UNLESS OTHERWISE NOTED.
THIS VALVE IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- . THE FIRST DASH NUMBER INDICATES FLOW RATE FROM PORT NO. 1 TO PORT NO. 2 IN TENTHS OF A GALLON PER MINUTE AT 2000 PSI DIFFERENTIAL PRESSURE. THE SECOND DASH NUMBER INDICATES FLOW RATE FROM PORT NO. 2 TO PORT NO. 1 IN TENTHS OF A GALLON PER MINUTE AT 2000 PSI DIFFERENTIAL PRESSURE. THE FIRST DASH NUMBER MUST BE LESS THAN THE SECOND DASH NUMBER AND THE SECOND DASH NUMBER MAY BE ANY NUMBER SHOWN IN THE ABOVE TABLE.
SEAL SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE MS PART NUMBER, THE WORD "RESTRICTOR", THE MANUFACTURER'S NAME OR TRADEMARK AND THE MANUFACTURER'S PART NUMBER SHALL BE PERMANENTLY MARKED ON THE HEX AND/OR FLANGE SURFACES SUCH THAT THE MARKING IS VISIBLE WHEN THE VALVE IS INSTALLED.

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE VALVE, MODULAR HYDRAULIC TWO-WAY RESTRICTOR 4,000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION

VALVE; AIRCRAFT HYDRAULIC RESTRICTOR

1. SCOPE

1.1 Scope.- This specification covers cartridge-type modular hydraulic restrictor valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Restrictor valves shall be of the following types:

Type I - One-way restrictor

Type II - Two-way restricotr

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified:

Specifications

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible, Waterproofed
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection Process, Magnetic-Particle
MIL-H-6875	Heat Treatment of Steels (Aircraft Practice) Process for
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-M-7911	Marking, Identification of Aeronautical Equipment, Assem Assemblies and Parts
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III Design, Installation, Tests and Data Requirements, General Specification for
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specification and Standards, Use of
MS-33540	Safety Wiring - General Practices for
MS-20995	Wire-Lock

Drawing

MS-	Valve, Restrictor, One-Way (Type I) - Modular, Envelope for
MS-	Valve, Restrictor, Two-Way (Type II) - Modular, Envelope for

2.2 Other Publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in the order of precedence set forth in MIL-STD-143. Where contractor materials and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualitication.- The restrictor valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and Processes.- Materials and processes used in the manufacture of these valves shall conform to the following requirements and to applicable specifications as defined in Section 2:

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion during the normal service life of the valve which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency.

Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero Stabilization of Steel.- Close-fitting, sliding steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic Parts.- Plastic parts shall be used only with the approval of the procuring agency for each application.

3.3 Parts.- Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the contractor's drawings.

3.4 Design and Construction

3.4.1 Envelope.- The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification, MS______________, or MS______________, and applicable drawings.

3.4.2 Hydraulic Fluid.- The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature Range.- The valves shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F.

3.4.4 Threads.- Only class 3, straight threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals.- Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with Standard Drawings MS-33540 and MS-20995.

3.4.7 Retainer Rings.- Except where they are positivel tained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valve.

3.4.8 Structural Strength.- The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure,temperature variations, and installation.

3.4.9 Weight.- The weight shall be kept to a minimum consistent with good design, and shall not exceed 0.15 pounds for Type I valves and shall not exceed 0.17 pounds for type II valves. The weight shall be specified on the applicable drawing.

3.4.10 Mounting Position.- The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow Control.- The restrictor valves shall be designed to provide the rated flow versus differential pressure, as shown for the corresponding identification dash number on the performance chart Figure 1. Only the dash numbers shown shall be used.

3.4.12 Filters.- Valves containing orifices whose smallest dimension is less than 0.070 inch in diameter shall be provided with filtration protection. The filter element shall consist of a wire mesh screen whose smallest hole dimension is not less than 0.008 inch and whose largest hole dimension is not greater than 0.012 inch.

3.4.13 Surface roughness.- Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's parts.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer s part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, shall be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification.- Each valve shall have the identifying markings placed on the hex head or the flange so that the identification can be read when the valve is installed in a manifold cavity. Each valve shall be permanently and legibly marked with the following information, per MIL-M-7911.

Valve, Restrictor

MS No., and appropriate dash number

Manufacturer's Part No.

Manufacturer's Name or Trademark

Type I valves shall have a dash number following the MS number indicating the flow rate in the restricted flow direction in tenths of a gallon per minute at 2,000 psi differential pressure, using Specification MIL-H-8446 fluid at 100+15°F. Type II valves shall have two separate dash numbers following the MS number to indicate the

flow rate in each direction in tenths of a gallon per minute at 2,000 psi differential pressure, using Specification MIL-H-8446 fluid at 100±15°F.

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contaminant. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical Defect Inspection.- All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated Pressure.- The valves shall be designed to operate in a hydraulic system having a rated pressure of 4,000 psi.

3.8.2 Operating pressure.- The valves shall be designed to insure satisfactory operation and service life throughout the operating range from 0 to 4,000 psi at rated flows per Figure 1, when tested per 4.6.3. The valves shall be capable of operation at 6,000 psi.

3.8.3 Proof Pressure.- The valves shall be capable of withstanding a proof pressure of 6,000 psi, when tested per 4.6.2; and there shall be no evidence of external leakage, permanent set, or other damage.

3.8.4 Flow Rate.- Flow rates of Type I and Type II valves shall fall within the limits of Figure 1 for the particular dash number size being rated, when tested per 4.6.3. Type I valves shall be flow rated in the direction of restricted flow. Type II valves shall be flow rated in both directions.

3.8.5 Erosion.- The valves shall meet the flow rate requirements of paragraph 3.8.4 after five hours of continuous operation with a pressure drop of 5,000 psi to 5,300 psi, when tested per 4.6.4.

3.8.6 Check valve operation of Type I valves.- Type I valves shall pass four gallons per minute in the free flow direction with a net pressure drop that shall not exceed 25 psi, when tested per 4.6.5. Net pressure drop shall be the difference in pressure drop across the test housing with the valve installed, and the pressure drop across the housing with the cavity plugged. In addition the valves shall meet the flow rate requirements of paragraph 3.8.4 after being subjected to 2,500 cycles of surge pressure at 4,000 psi, when tested per 4.6.5.

3.8.7 Endurance.- The valves shall meet the requirements of paragraphs 3.8.3 and 3.8.4 after 50,000 cycles of operation when tested per 4.6.6.

3.8.8 Vibration.- The valves shall meet requirements of paragraph 4.6.3.2 after being subjected to vibration from 5 to 2,000 cps at an amplitude of 0.04 inch (0.08 inch total excursion) or 15"g"s whichever is limiting, when tested per 4.6.7.

3.8.9 Burst Pressure.- When 10,000 psi is applied to the valves per 4.6.8, there shall be no evidence of rupture of internal or external parts.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.- The manufacturer is responsible for the performan of all acceptance tests prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the

examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests.- The inspection and testing of restrictor valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests.

4.3.1 Sampling instructions

4.3.1.1 Samples of restrictor valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Tests.- The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2.

(c) Flow rate per 4.6.3.

(d) Erosion test per 4.6.4.

(e) Check valve operation of Type I valves per 4.6.5.

(f) Endurance per 4.6.6.

(g) Vibration per 4.6.7.

(h) Burst pressure per 4.6.8.

4.4 Acceptance Tests.- Acceptance tests shall be performed on individual values or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each check valve shall be subjected to the following tests:

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2

(c) Flow rate per 4.6.3.

4.5 Test Conditions

4.5.1 Test Fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid Temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination.- Standard fine air cleaner test dust or approved contaminate mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of Particle	Percent by Weight of Total
0 to 5 micron	39±2
5 to 10 micron	18±3
10 to 20 micron	16±3
20 to 40 micron	18±3
Over 40 micron	9±3

4.5.4 Filtration.- The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test Housing

4.5.5.1 Qualification Test Housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity and which is acceptable to the procuring agency.

4.5.5.2 Acceptance Test Housing.- The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test Methods

4.6.1 Examination of Product.- Each valve shall be carefully examined to determine conformance with the requirements of this specification for workmanship, marking, conformance to applicable drawings, or for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of +5 micro-inches at the level being measured.

4.6.2 Proof Pressure.

4.6.2.1 Proof pressure for Qualification.- Hydraulic pressure shall be applied simultaneously to both ports at a rate not exceeding 25,000 psi per minute until 6,000 psi is reached. The proof pressure shall be held for a minimum of 2 minutes. There shall be no evidence of external leakage, permanent set, or other damage. The fluid temperature shall be 450±15°F. for this test.

4.6.2.2 Proof pressure for Acceptance.- The test shall be conducted per 4.6.2.1 except that the fluid temperature shall be 95±15°F.

4.6.3 Flow Rate.- Type I valves shall be flow rated in the direction of restricted flow, and Type II valves shall be flow rated in both directions. The valve test housing shall be installed four tube diameters downstream from the pressure pickup and fifteen tube diameters upstream from the return pickup.

4.6.3.1 Flow rate for Qualification.- Flow rate shall be measured at the following differential pressures: 100 to 105; 490 to 510; 1,980 to 2,020; and 3,970 to 4,030 psi with Specification MIL-H-8446 fluid at a temperature of -65±5°F; +100±5°F, and +450±15°F. The flow must fall within the limits of Figure 1 for the par particular dash size being tested.

4.6.3.2. Flow rate for Acceptance.- Flow rate shall be measured at a differential pressure of 1,980 to 2,020 psi with the Specification MIL-H-8446 fluid at a temperature of 100±5°F. The flow shall fall within the limits of Figure 1 for the particular dash size being tested.

4.6.4 Erosion Test.

4.6.4.1 Erosion test at Room Temperature.- Restrictor valves shall withstand 5 hours of continuous operation in each direction of restricted flow at such a flow that the pressure drop across the valve is 5,000 to 5,300 psi. The gage pressure at the inlet to the valve shall not exceed 6,000 psi. The fluid temperature shall be maintained at 95±15°F at the inlet to the valve.

4.6.4.2 Erosion Test at High Temperature.- The erosion test of 4.6.4.1 shall be repeated except that the inlet temperature shall be maintained at 450±15°F. At the conclusion of this test the flow rate test of 4.6.3.2 shall be performed and the requirements thereof satisfied.

4.6.5 Check valve operation of Type I Valves.-

4.6.5.1 Pressure Drop.- The fluid temperature shall be 95±15°F for this test. The net pressure drop shall be measured for a flow of 4 GPM in the free flow direction and shall not exceed 25 psi. The new pressure drop is obtained as the difference in the pressure drop across the test housing with the valve installed and the pressure drop across the test housing with the cavity opening plugged.

4.6.5.2 Surge Flow Test.- A test set up similar to Figure 2 shall be used for the surge flow test. The air precharge pressure shall be 1,300±50 psi and the hydraulic system pressure shall be 4,000 psi. The directional control valve shall be operated in the following sequence for 2500 complete cycles. The following sequence shall constitute one complete cycle:

(a) The directional control valve shall be in a neutral position to permit the build up of 4,000 psi hydraulic pressure in the accumulator.

(b) The control valve shall be quickly actuated to permit flow through the restrictor in the free flow direction.

(c) When the pressure drops to 1,300±50 psi the control valve shall be returned to the neutral position to permit the build up of 4,000 psi pressure.

(d) The directional control valve shall then be actuated to direct flow through the restrictor in the restricted flow direction. The selector valve shall remain in this position for at least 3 seconds and then returned to the neutral position.

Following this test the valve shall be tested per 4.6.3.2 and shall meet the requirement thereof.

4.6.6 Endurance.- A test set-up similar to Figure 3 shall be used for the endurance test.

4.6.6.1 Endurance For Type I Valves.- Type I valves shall be subjected to 50,000 dynamic cycles while undergoing a series of 7 time-temperature spectrums per Figure 4. The first, fourth, and seventh repetitions of this spectrum shall begin at -65°F while the other repetitions shall begin at 95±15°F. Each dynamic cycle shall consist of flow of 4 GPM in the free flow direction, followed by a reversal of flow direction accompanied by a pressure peak of 6,000±200 psi in the restricted direction. The dynamic cycling rate shall be 17-20 cpm. At the conclusion of this test the flow rate test of 4.6.3.2 and the proof pressure test of 4.6.2.2 shall be performed and the requirements satisfied.

4.6.6.2 Endurance for Type II Valves.- Type II valves shall be subjected to 50,000 impulse cycles in each direction while undergoing seven repetitions of the time-temperature spectrum shown in Figure 4. The first, fourth, and seventh repetitions of the spectrum shall begin at -65°F while the other spectrums begin at 95±15°F. Each cycle shall consist of a pressure peak of 6,000±200 psi in each direction. Impulse cycling shall be at a rate of 17-20 cpm. At the conclusion of this test the flow rate test of 4.6.3.2 and the proof pressure test of 4.6.2.2 shall be performed and the requirements satisfied.

4.6.7 Vibration.- With the fluid temperature maintained at 95±15°F, the valve shall be cycled by alternately imposing rated flow in one direction and then the other direction at the rate of 15±5 cycles per minute. While the valve is being cycled in this manner it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2,000 cycles per second in 30 minutes. The amplitude shall be 0.04 inches (0.08 inch total excursion) or 15 G's, whichever is limiting. This test shall be repeated, and the frequency of any and all resonant points shall be noted.

Vibrate the valve for 90 minutes at the most severe resonant frequency noted above at 0.08 inch total excursion or 15 G's,whichever is less severe. If no resonant frequency is found the valve shall be vibrated for 90 minutes at 500 cps. The above procedure shall be repeated with the direction of vibration changed 90° horizontally and again with the direction of vibration changed to vertical. After completion of the vibration test the valve shall be tested per 4.6.3.2 and shall be within the limits specified.

4.6.8 Burst Pressure.- Pressure, applied to both ports simultaneously or to either port with the other port plugged, shall be increased at a rate not to exceed 25,000 psi per minute until 10,000 psi is reached. This pressure shall be held for two minutes without rupture of internal or external parts. The fluid temperature shall be 95±15°F for this test. The valve shall be removed from the test manifold and visually inspected for any mechanical failures.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging.- Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and them drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of Shipments.- Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document

Name of part

MS part No.

Month and year of manufacture

6. NOTES

6.1 Intended use.- The restrictor valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891, and operating with hydraulic fluid conforming to Specification MIL-H-8446 at pressures which do not exceed 4,000 psi. The restrictor valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering Data.- Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number including dash number designating flow rate.

(c) Federal Stock Number

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

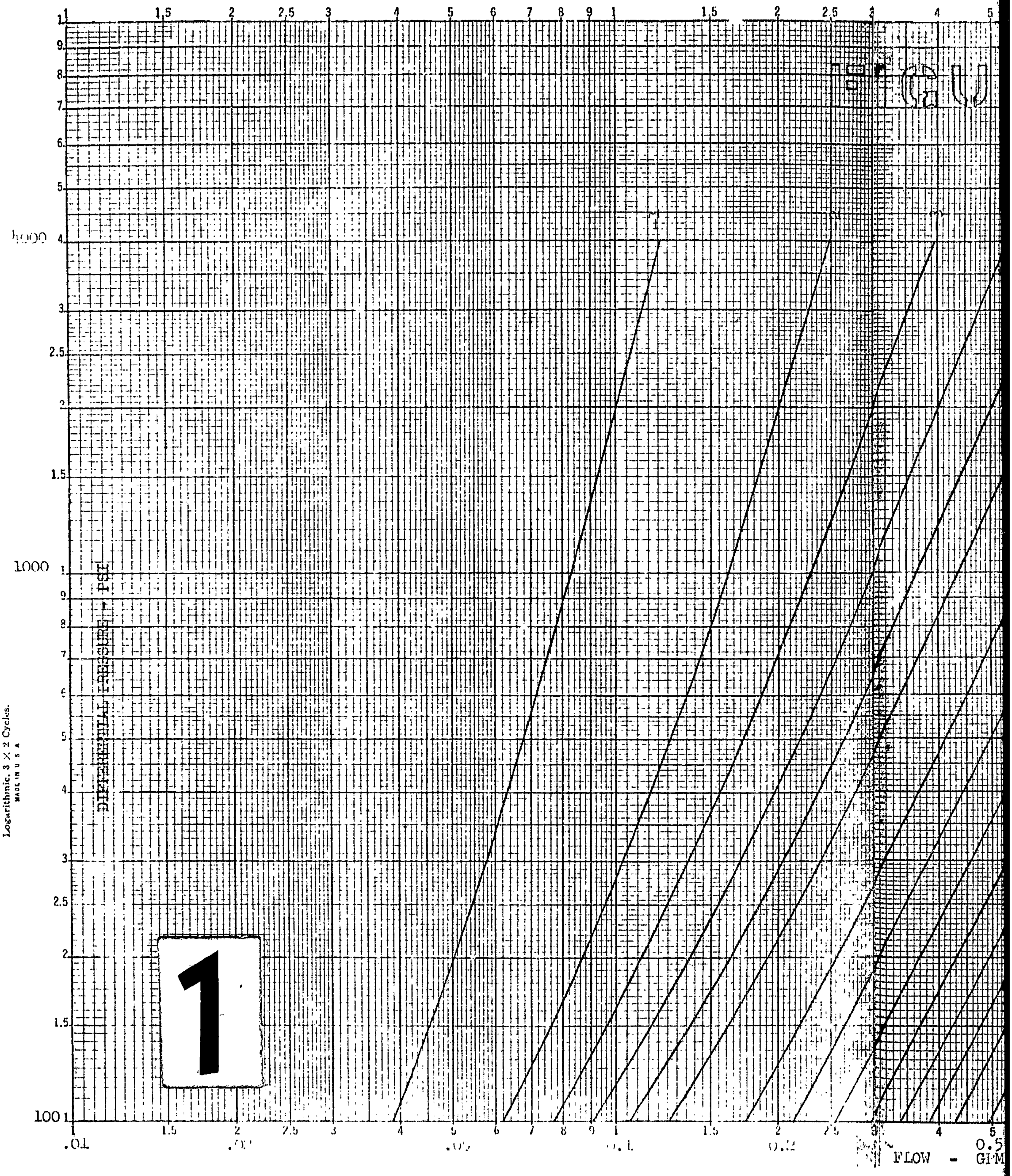
Custodians:

Navy - Bureau of Naval Weapons

Air Force

Preparing activity:

Navy - Bureau of Naval Weapons


DIFFERENTIAL PRESSURE - PSI
1000
100
.01
0.1
0.5
FLOW - GPM
1

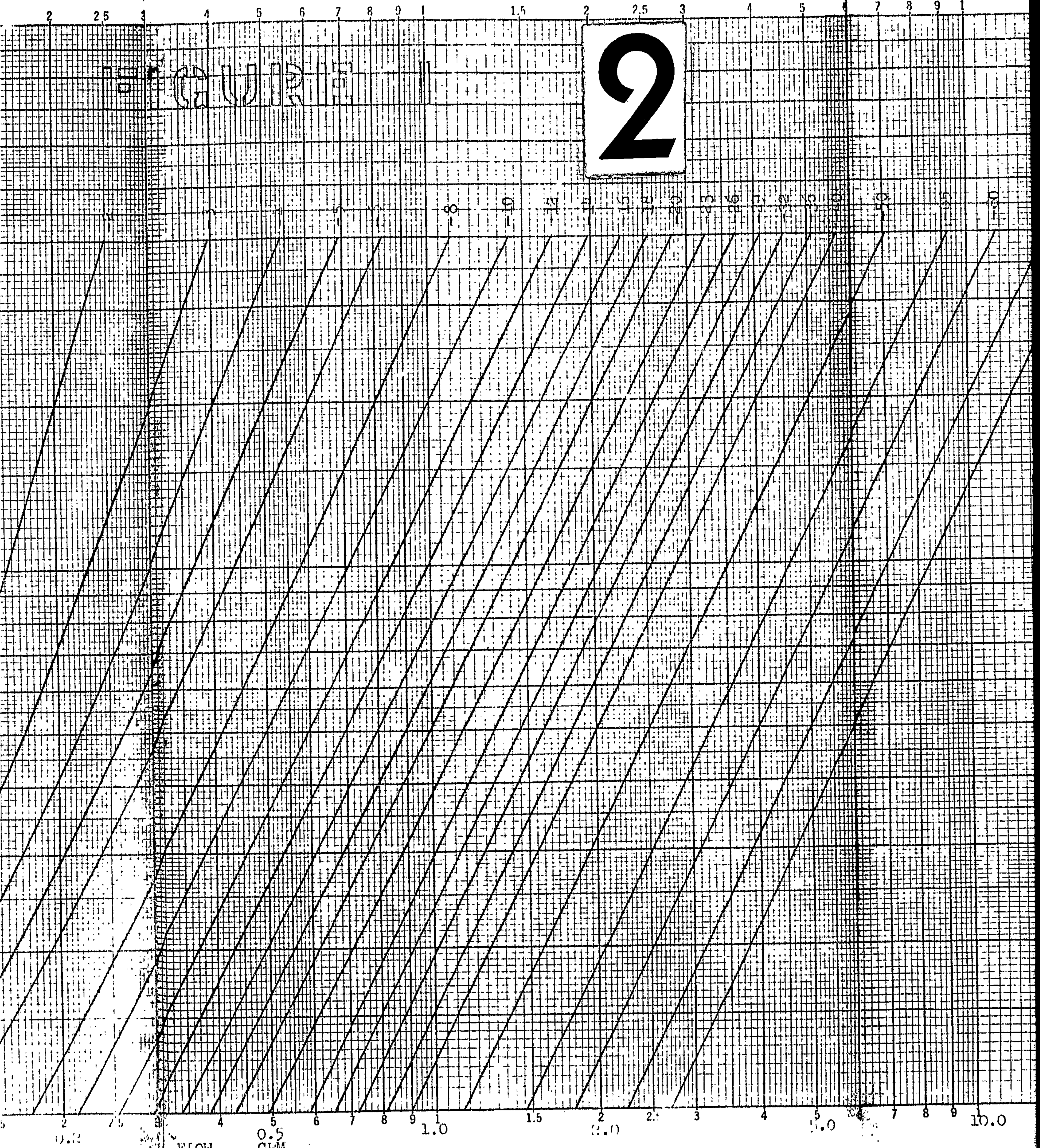
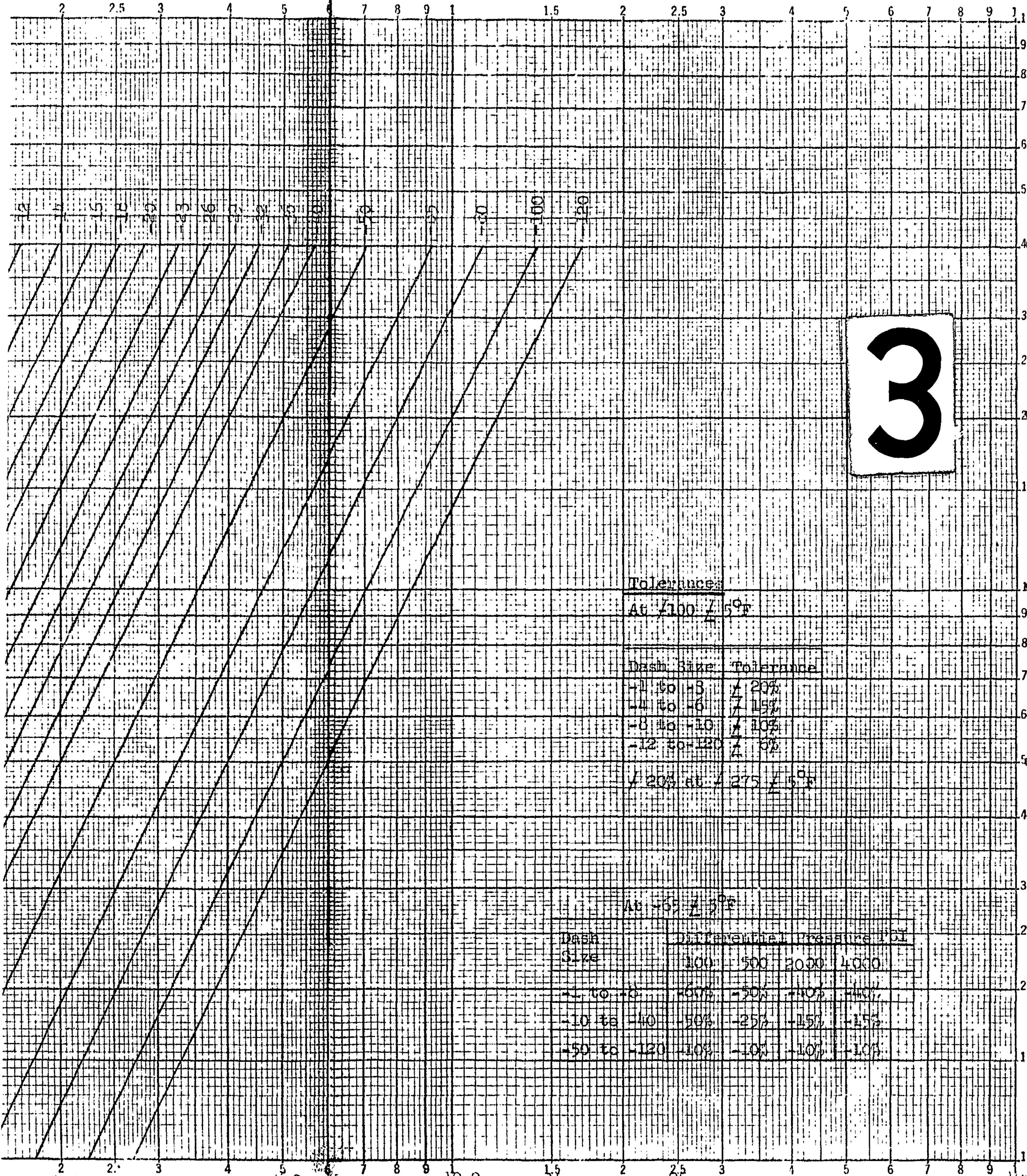


FIGURE 1
2
0.2
0.5
1.0
2.0
5.0
10.0
FLOW - GPM



Tolerance:

At +100 ± 5°F

Dash Size	Tolerance
-1 to -3	± 20%
-4 to -6	± 15%
-8 to -10	± 10%
-12 to -120	± 5%

± 20% at + 275 ± 5°F

At -65 ± 5°F

Dash Size	Differential Pressure PSI			
	100	500	2000	4000
-1 to -8	-60%	-50%	-40%	-40%
-10 to -40	-30%	-25%	-15%	-15%
-50 to -120	-10%	-10%	-10%	-10%

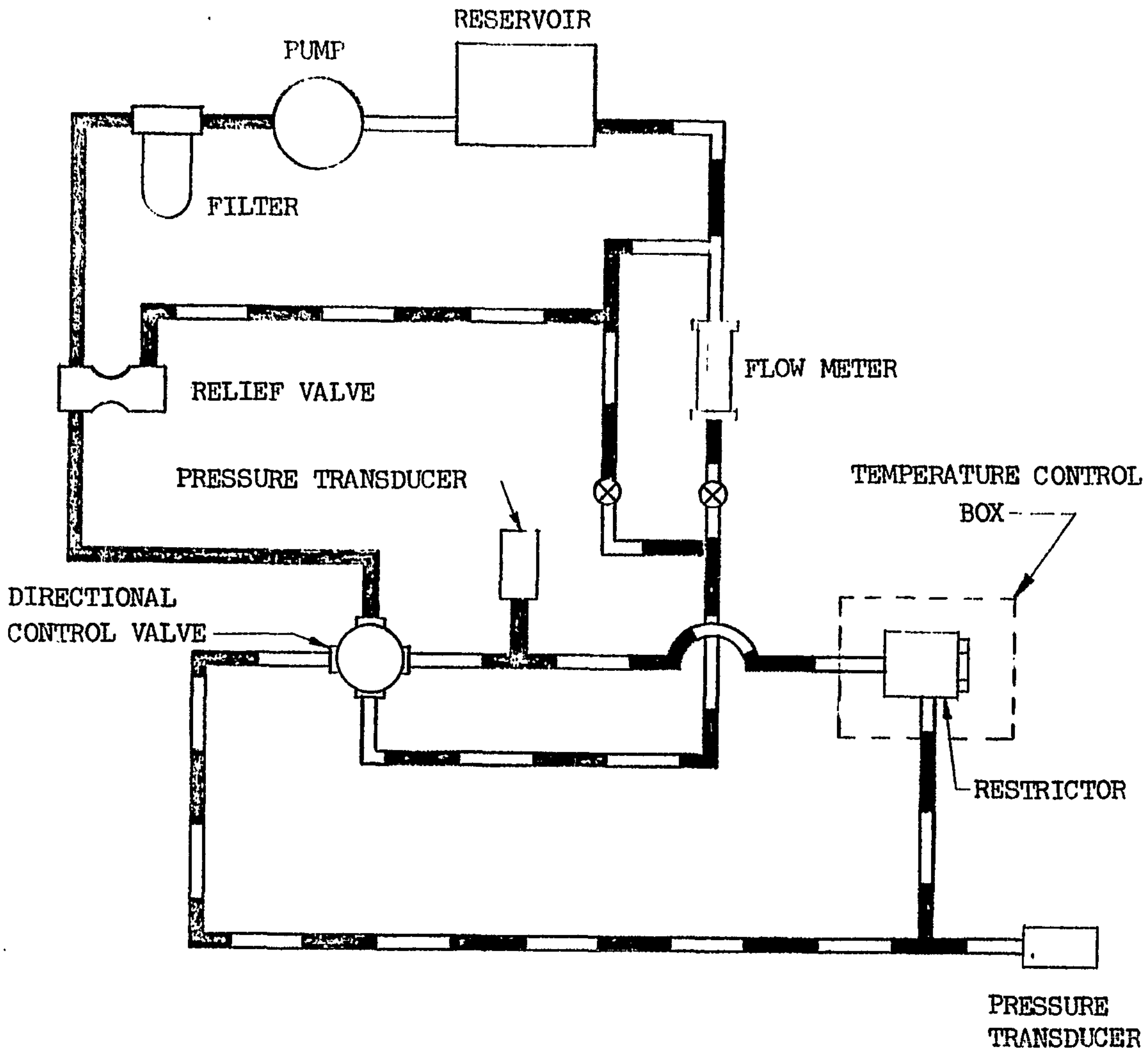


FIGURE 3

TYPICAL SET UP FOR ENDURANCE TEST

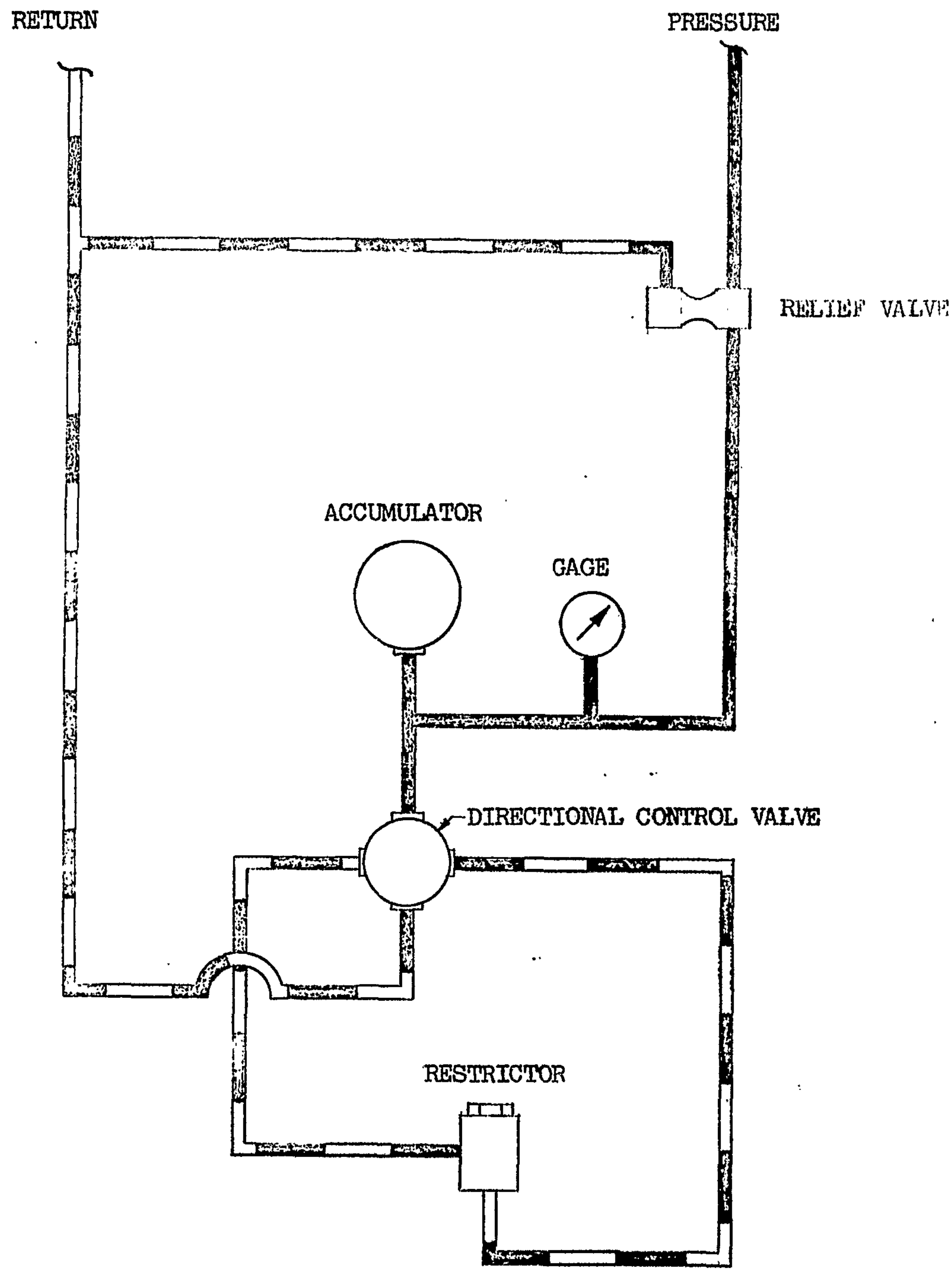


FIGURE 2

TYPICAL SET UP FOR SURGE FLOW TEST

NOTES:

1. Rate of temperature rise or decay may vary within the shaded area shown.
2. Six and one half hours of endurance cycling are to be run in one day. Components are to be soaked 8 hours or overnight at the low temperature required to start the following day of testing.
3. The ambient temperature shall be maintained between 450 - 650°F during the time from the 2nd hour through the 5th hour of the spectrum shown.

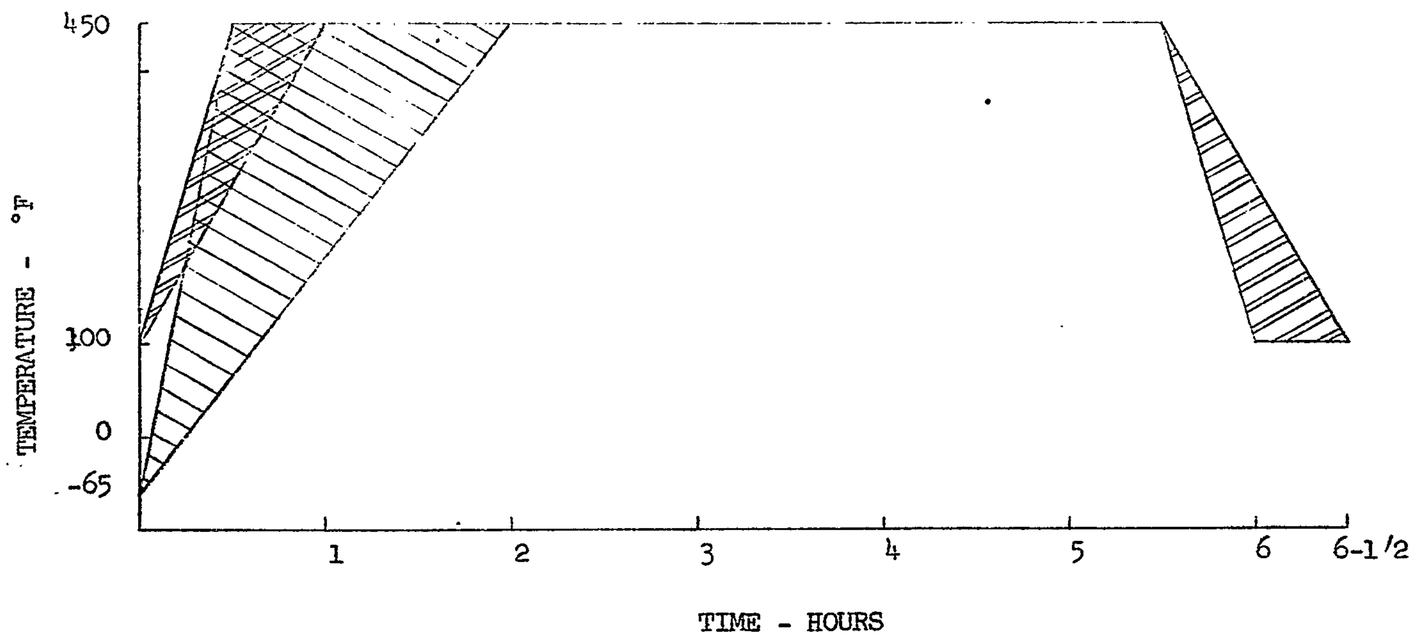
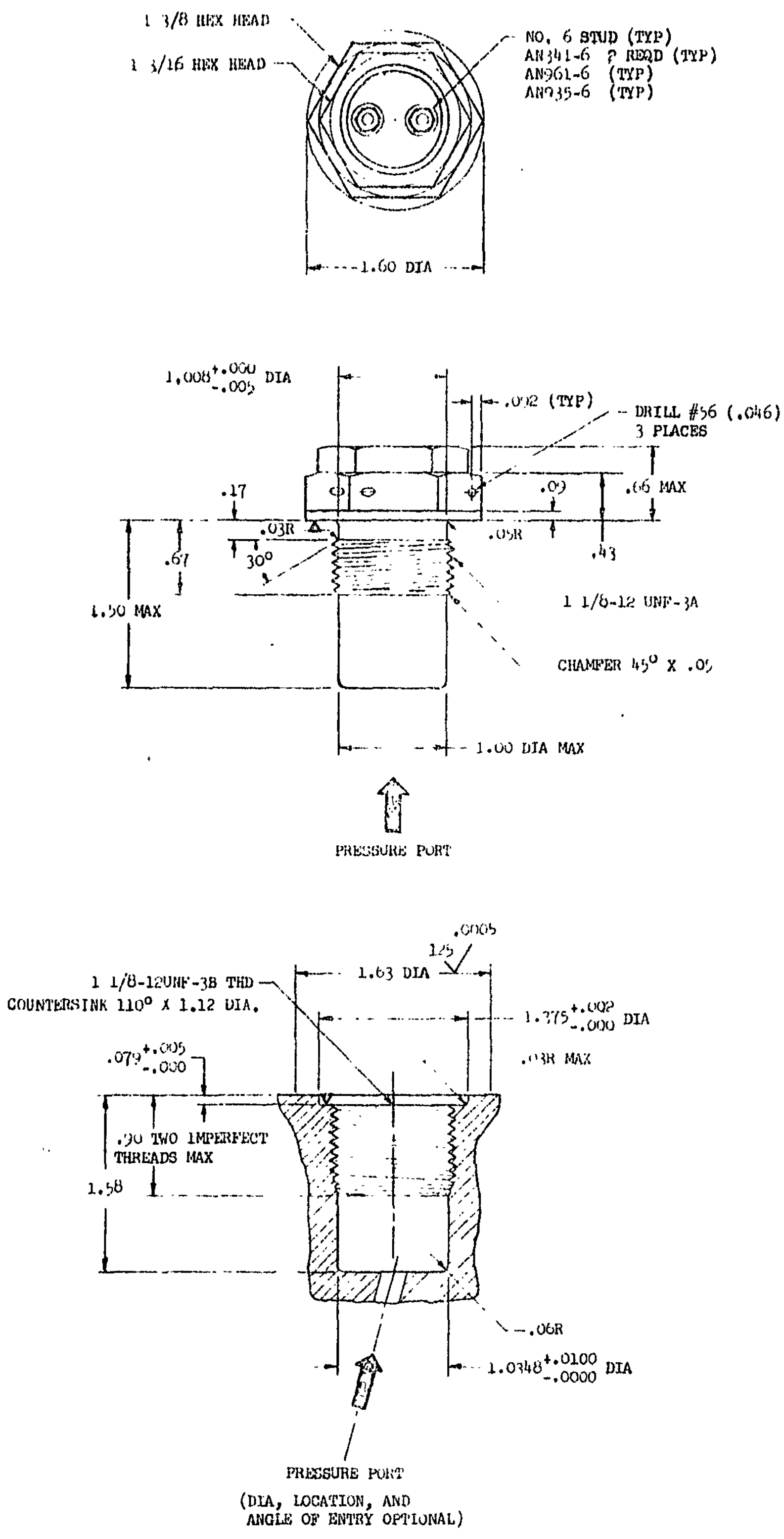


FIGURE 4

APPENDIX III

Suggested MIL Specification for Pressure Switch
Suggested MS Standard for Pressure Switch

FED. SUP CLASS



REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **SWITCH, MODULAR HYDRAULIC PRESSURE** 4000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

FED. SUP CLASS

PART NUMBER	CIRCUIT OPENING PRESSURE PSI	WEIGHT POUNDS
MS- -1	ADJUSTIBLE FROM 500 TO 3800	.40 MAX
MS- -2	3800	.40 MAX

DETAIL REQUIREMENTS

TEMPERATURE LIMITS - +450°F FLUID AND +650°F AMBIENT MAXIMUM, -65°F MINIMUM.
PRESSURE - OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI.
FLUID - SPECIFICATION MIL-H-8446.
SEALS - MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE.

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL △) SHALL BE 16/ RHR. ALL OTHER SURFACES 125/ RHR.
TOLERANCES:
LINEAR TOLERANCE: ±.01 UNLESS OTHERWISE NOTED.
ANGULAR TOLERANCE: ±2° UNLESS OTHERWISE NOTED.
THIS PRESSURE SWITCH IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI, TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL-
SEALING SURFACES ARE DENOTED BY THE SYMBOL △.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE MS PART NUMBER, THE WORDS "PRESSURE SWITCH", THE MANUFACTURER'S NAME OR TRADEMARK, AND THE MANUFACTURER'S PART NUMBER SHALL BE PERMANENTLY MARKED ON THE HEX AND/OR FLANGE SURFACES SO THAT THE MARKING IS VISIBLE ON INSTALLATION. TYPE I SWITCHES (ADJUSTABLE) SHALL HAVE THE PRESSURE SETTING MARKED IN A TEMPORARY MANNER IN ADDITION TO THE ABOVE.

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **SWITCH, MODULAR HYDRAULIC PRESSURE** 4000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION
PRESSURE SWITCH, HYDRAULIC

1. SCOPE

1.1 Scope.- This specification covers cartridge-type modular hydraulic pressure switches, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- The pressure switches shall be of the following classes:

Class 1 - 0 to 4,000 psi - adjustable
Class 2 - 0 to 4,000 psi - non-adjustable

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

Specifications

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material Greaseproof, Flexible, Waterproof
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection, Process Magnetic Particle
MIL-H-6875	Heat Treatment of Steels, (Aircraft Practice) for
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III, Design, Installation, Tests and Data Requirements, General Specification for
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specifications Standards, Use of
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MS-33540	Safety Wiring - General Practice for
MS-20995	Wire-Lock
MS-3102	Connectors

Drawing

MS-

2.2 Other publications.- Where it becomes necessary to use publications other than those listed in 2.1., they shall be selected in order of precedence set forth in MIL-STD-143. Where Contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate test and inspection.

3. REQUIREMENTS

3.1 Qualification.- The hydraulic pressure switch furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes.- Materials and processes used in the manufacture of these switches shall conform to the following requirements and to the applicable specifications as defined in Section 2.

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion during the normal service life of the valve which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency. Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel.- Close-fitting, sliding steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic Parts.- Plastic parts shall be used only with the approval of the procuring activity, for each application.

3.3 Parts.- Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the manufacturer's drawings.

3.4 Design and construction

3.4.1 Envelope.- The external configurations, dimensions, and other details of the design shall conform to the requirements of this specification and MS-______.

3.4.2 Hydraulic fluid.- The switches shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range.- The switches shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F.

3.4.4 Threads.- Only class three straight threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals.- All seals shall be of metallic construction and shall be approved by the procuring activity.

3.4.6 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety-wire shall be applied in accordance with standard drawings MS-33540 and MS-20995.

3.4.7 Retainer rings.- Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow-apart or jamming of the switch.

3.4.8 Structural strength.- The switches shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installations.

3.4.9 Weight.- The weight shall be kept to a minimum consistent with good design, and shall be specified on applicable drawing.

3.4.10 Mounting position.- The switches shall satisfy the performance requirements when mounted in any position.

3.4.11 Electrical switch and electrical connector.- A single-pole double-throw switch shall be used. The circuit and terminal arrangements shall conform with the applicable detail drawing. The connector used shall conform to MS-3102.

3.4.11.1 Current capacity.- Pressure switches shall be capable of operating in a 28 volt d.c. electrical system and a 115 volt, 400 cycle, a.c. electrical system.

3.4.11.2 Class 1 switches.- Class 1 adjustable switches shall be designed to open the electrical contacts between the pressure range of 500 psi and 3800 psi ± 25 psi during increasing hydraulic pressure and to close the electrical contacts at 500 psi below a selected open contact setting, within the range specified above, during decreasing hydraulic pressure, when tested per 4.6.3.

3.4.11.3 Class 2 switches.- Class 2 non-adjustable switches shall be designed to open the electrical contacts at 3800 psi ± 25 psi during increasing hydraulic pressure and to close the electrical contacts at 500 psi below the open contact setting during decreasing hydraulic pressure, when tested per 4.6.3.

3.4.11.4 Electrical insulation.- Electrical insulation shall be capable of withstanding 1,000 volts rms when tested per 4.6.4, without showing evidence of cracking, charing or burning.

3.4.12 Surface roughness.- Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's parts.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies composed of selected mating components, shall be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Switches shall be self-contained components such that a switch may be removed from one housing and inserted into another housing without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification.- Each switch shall have the identifying markings placed on the hex-head or the flange so that the identification can be read when the switch is installed in the manifold cavity. Each switch shall be permanently and legibly marked with the following information per MIL-M-7911.

Switch, Hydraulic Pressure
MS- number
Manufacturer's Part Number
Manufacturer's Name or Trade Mark

In addition, the open contact setting shall be stamped into a metal tag which is attached to the safety-wire securing the adjustment or adjustment cover.

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficient high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling and packaging switches to assure that the components are clean and free of contamination. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection.- All magnetizable highly stressed parts shall be subject to magnetic inspection per Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subject to fluorescent penetrant inspection per specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated pressure.- The pressure switches shall be capable of operation in a hydraulic system with a rated pressure of 4,000 psi.

3.8.2 Operating pressure.- The pressure switches shall be designed to insure satisfactory operation throughout the operating range of 0 to 4,000 psi when tested per 4.6.3.

3.8.3 Proof pressure.- The pressure switches shall be designed to withstand a proof pressure of 6,000 psi with a fluid temperature of 450°F. There shall be no evidence of leakage, permanent set, or other damage that could cause malfunctioning of the switch throughout the service life, when tested per 4.6.2.

3.8.4 Burst pressure.- The pressure switches shall be designed to withstand a minimum burst pressure of 10,000 psi at room temperature, when tested per 4.6.10.

3.8.5 Electrical circuit.- The electrical circuit of the pressure switches shall operate satisfactorily when tested at the contact opening and closing pressures specified in paragraphs 4.6.3.1 and 4.6.8.

3.8.6 Shock.- The pressure switches shall be capable of satisfactory operation after being subjected to a 50 "g" shock along each of three mutually perpendicular axes, when tested per 4.6.5.

3.8.7 Endurance.- The pressure switches shall be capable of satisfactory operation while being subjected to 50,000 cycles of operation, when tested per 4.6.6.

3.8.8 Immersion.- The pressure switches shall show no evidence of leakage while being soaked in a saturated solution of sodium chloride, when tested per 4.6.7.

3.8.9 Corrosion.- The pressure switches shall be capable of satisfactory operation after being subjected to salt spray for a minimum of 200 hours. There shall be no evidence of deterioration or corrosion which would limit the service life of the switches, when tested per 4.6.9.

3.8.10 Vibration.- The pressure switches shall be capable of satisfactory operation when vibrated at 5 to 2000 cps at an amplitude of 0.04 inch (0.08 inch total excursion) or 15 "g"s whichever is limiting, when tested per 4.6.8. The switch contacts shall possess a closed circuit sensitivity and open circuit sensitivity of not more than 10 milliseconds for each action.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.- The manufacturer is responsible for the performance of all acceptance tests prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests.- The inspection and testing of pressure switches shall be classified as follows:

(a) Qualification tests
(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of pressure switches for qualification tests shall consist of one specimen of each design for which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing the adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Tests.- The qualification tests shall consist of the following tests:

(a) Examination of product per 4.6.1.
(b) Overpressure test per 4.6.2.1.
(c) Signal light test per 4.6.3.1.
(d) Insulation test per 4.6.4.
(e) Shock test per 4.6.5.
(f) Endurance test per 4.6.6.
(g) Immersion test per 4.6.7.
(h) Vibration test per 4.6.8.
(i) Salt spray test per 4.6.9.
(j) Burst pressure test per 4.6.10.

4.4 Acceptance tests.- Acceptance tests shall be performed on individual switches or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each switch shall be subjected to the following tests:

(a) Examination of product per 4.6.1.
(b) Overpressure test per 4.6.2.2.
(c) Signal light test per 4.6.3.2.

4.5 Test Conditions.

4.5.1 Test fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95 ± 15°F for that particular test.

4.5.3 Test housing

4.5.3.1 Qualification test housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity and which is acceptable to the procuring activity.

4.5.3.2 Acceptance test housing.- The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test methods

4.6.1 Examination of product.- Each pressure switch shall be carefully examined to determine conformance with the requirement of this specification for workmanship, marking, conformance to applicable drawings, or for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Overpressure test

4.6.2.1 Overpressure test for qualification.- The pressure switch and fluid shall be stabilized at 450°F. Hydraulic pressure of 6,000 psi shall be applied to the pressure switch and held for ten minutes. There shall be no evidence of external leakage, permanent set or other damage.

4.6.2.2 Overpressure test for acceptance.- The pressure switch and fluid shall be stabilized at 95 ± 15°F. Hydraulic pressure of 6,000 psi shall be applied to the pressure switch and held for ten minutes. There shall be no evidence of external leakage, permanent set or other damage.

4.6.3 Signal light test

4.6.3.1 Signal light test for qualification.- The pressure switch and fluid shall be stabilized at 95 ± 15°F. Test apparatus shall include a temperature control chamber, a variable hydraulic pressure fluid supply, pressure indicating devices and a three candlepower, 24-28 volt indicating lamp with an applied voltage source of 28 ± 1 volt, d.c. Adjustable switches shall be adjusted to open the circuit at 525 ± 25 psi during increasing pressure. The pressure shall be applied gradually from zero to the point at which the circuit through the lamp load is opened. The pressure shall be reduced until the circuit through the lamp load is closed. Record the pressures that open and close the switch. The closing of the circuit during decreasing pressure shall be

500 psi below the recorded pressure that opened the circuit. This procedure shall be repeated for adjustable switches for each of the following settings ± 25 psi: 1,500 psi, 2,500 psi, 3,000 psi, 3,500 psi, and 3,800 psi. Non-adjustable switches shall be tested at 3,800 ± 25 psi.

4.6.3.2 Signal light test for acceptance.- The pressure switch and fluid temperature shall be stabilized at $95^{\circ} \pm 15^{\circ}$F. The test apparatus shall be per 4.6.3.1. Adjustable switches shall be adjusted to the setting specified in the procuring document. The test procedure shall be per 4.6.3.1, except applied hydraulic pressure shall be continuously increased to 4,000 psi prior to decreasing pressure. Non-adjustable switches shall be tested at 3,800 ± 25 psi.

4.6.4 Insulation test.- This test shall be performed after the pressure switch has been soaked for 8 hours at an ambient temperature of 650°F or higher. The test shall be conducted with the switch at a temperature of 650°F or more. Pressure of 4000 psi shall be applied to the switch. With one conductor attached to the switch body and one to a terminal a potential of 1000 volts root mean square, 60 cycle, alternating current, shall be applied for one minute. At the end of this period the insulation around the terminals shall be examined. The insulation shall show no evidence of cracking, charing, or burning, The switch shall then be subjected to signal light test, 4.6.3.1, and shall meet the requirements thereof.

4.6.5 Shock test.- The equipment and procedure for this test shall be as specified in Standard MIL-STD-202, Method 202A. The pressure switch shall be installed in the test housing and mounted on a movable carriage assembly. A force of 50 gravity units shall be applied in the direction of each of the three major axes. The switch shall then be subjected to the signal light test, 4.6.3.1, and shall meet the requirements thereof.

4.6.6 Endurance test.- The pressure switch shall experience five repetitions of the time-temperature spectrum shown in Figure 1 while it is endurance cycled. The

first, third, and fifth spectrums shall begin at -65°F while the second and fourth repetitions of the spectrum shall begin at room temperature. The switch shall be connected to a source of direct current maintained at 28 ± 1 volts with the lamp load in series between the two terminals. With the switch setting at 3800 ± 25 psi it shall be operated by increasing the pressure from zero to 4,000 psi and then decreasing the pressure to zero. This shall be repeated for 50,000 cycles. The rate of pressure cycling shall be 25-26 cycles per minute so that 10,000 cycles can be run in one time-temperature spectrum. The switch shall then be subjected to the signal light test, 4.6.3.1, and shall meet the requirements thereof.

4.6.7 Immersion test.- The pressure switch shall be installed in a test housing and the hydraulic pressure port shall be plugged. The switch shall be immersed in a bath of a saturated solution of sodium chloride at a temperature of 150° ± 10°F. The absolute pressure of the air above the liquid shall then be reduced to approximately 1 inch of mercury and maintained for 1 minute, or until air bubbles substantially cease to be given off by the liquid, whichever is longer. The absolute pressure shall then be increased to 2 1/2 inches of mercury. Any bubbles coming from within the valve shall be considered as leakage. Leakage shall be cause for rejection. Bubbles which are the result of intrapped air on the various exterior parts of the case shall not be considered as a leak. After completion of the immersion test the switch shall be washed in clear water, and surface moisture shall be removed from the switch by circulating air at room temperature or wiping with a clean, dry cloth, or both. Within 30 minutes after removal of the switch from the immersion tank, the switch shall be tested per paragraph 4.6.3.1 and shall meet the requirements thereof.

4.6.8. Vibration test.- The following steps shall be followed in the order listed for class 1 and 2 switches:

(a) Prior to this test, the pressure setting of adjustable switches shall be adjusted to each extreme position 15 times and then be set to open the electrical

NOTES:

1. Rate of temperature rise or decay may vary within the shaded areas shown.
2. Approximately six and one half hours of endurance cycling are to be run in one spectrum.
3. The ambient temperature shall be maintained between 450 and 650°F during the time from the 2nd hour though 5 1/2 hours of the spectrum shown.

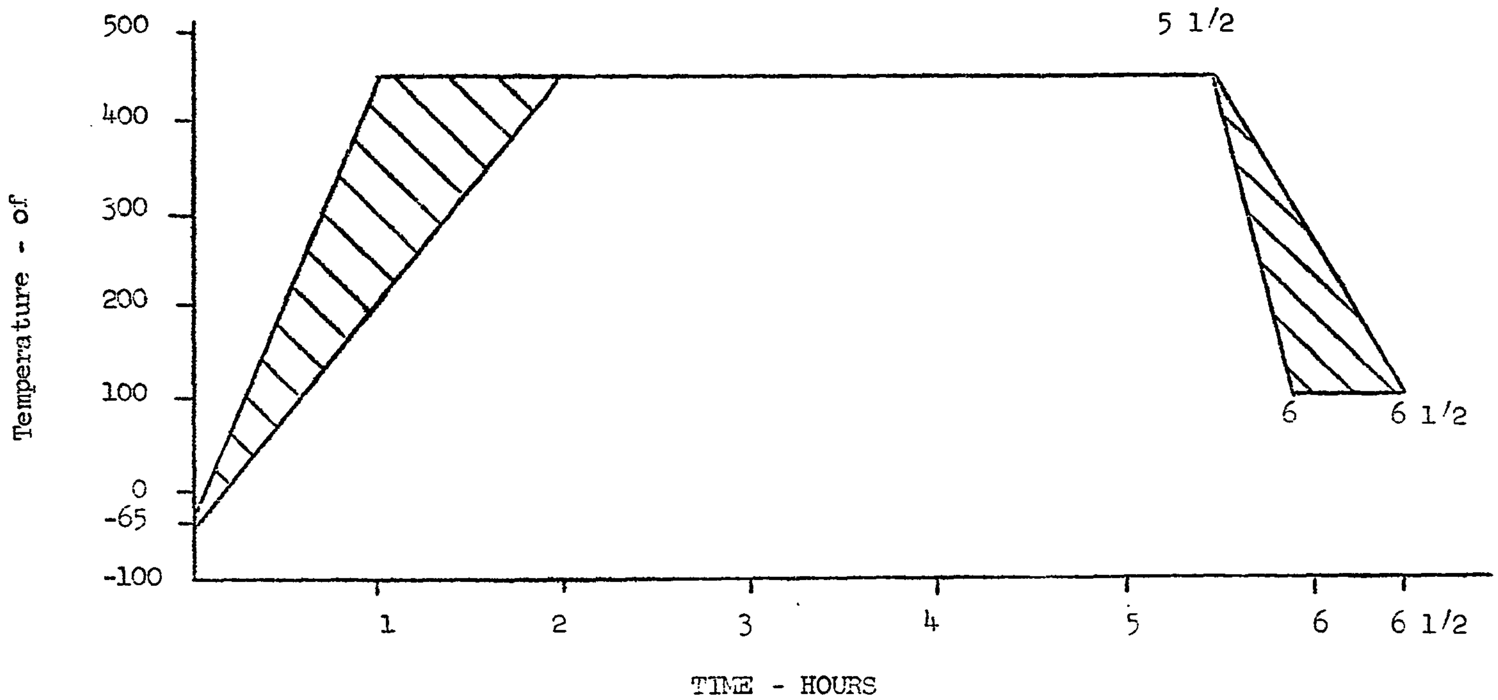


FIGURE 1
TIME-TEMPERATURE SPECTRUM

contacts at 3800 ± 25 psi. The switch shall be wired in series with a 3 candle-power 24-28 volt indicating lamp and a 28 ± 1 volt DC source of electricity. The fluid temperature shall be maintained at 25° ± 15°F. The switch shall then be cycled 17-20 cpm by raising the pressure to 4000 psi and then reducing the pressure to zero. While the switch is being cycled in this manner it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2000 cps in thirty (30) minutes. The amplitude shall be .04 inch (0.08 inch total excursion) or 15 "g"s whichever is limiting. This test shall be repeated two times and during this time the frequency of any and all resonant points shall be noted. Vibrate the switch for ninety (90) minutes at the most critical resonant frequency noted above at 0.08 inch total excursion or 15 "g"s whichever is least severe. If no resonant frequency is noted the switch shall be vibrated at 500 cps for 90 minutes. The signal light shall indicate the rise and drop in pressure while vibrating at resonant frequency. At 23 minute intervals during this 90 minute test and at a frequency 10% above or below the natural frequency, a test shall be made to assure that the setting pressures at which the contacts open and close are within the required limits. The contacts shall open with increasing pressure at 3800 ± 25 psi and the contacts shall close with decreasing pressure between the range of opening pressure and opening pressure minus 500 psi. After the 90 minute test and while the switch is vibrated at resonant frequency a pressure of 3900-4000 psi shall be applied to the switch. The switch shall possess a closed circuit sensitivity of not more than 10 milli-seconds as measured with an oscilliscope. After reducing pressure to zero apply a pressure of 2400-2500 psi. The switch shall possess an open circuit sensitivity of not more than 10 milli-seconds while being vibrated at resonant frequency.

(b) The procedure in (a) above shall be repeated with the direction of vibration changed 90° horizontally.

(c) The procedure in (a) above shall be repeated with the direction of vibration changed to vertical.

(d) The switch shall then be subjected to the signal light test of 4.6.3.1 and shall meet the requirements thereof.

4.6.9 Salt spray test.- The test set up for the salt spray test shall be in accordance with specification Federal Test Method Standard No. 151, Method 811. The component shall be installed in the test housing and mounted in the test chamber with the hydraulic port plugged. The component shall be subjected to the salt spray not less than 200 hours. At the conclusion of the test period, salt deposits may be removed and the component dried for 6 hours in a forced-draft oven at approximately 135°F. The component shall then be examined. Deterioration or corrosion which could prevent the component from meeting the required service life shall be cause for rejection. The component shall then be subjected to and shall meet the tests specified in 4.6.3.1.

4.6.10 Burst pressure test.- The pressure switch and fluid shall be stabilized at room temperature. A hydraulic pressure of 10,000 psi shall be applied to the pressure switch. There shall be no rupture of internal or external parts at any pressure below 10,000 psi.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging.- Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components, except electrical parts, shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments.- Interior packages and interior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following;

Stock No. as specified in the purchase document
Name of part
MS Part No.
Month and year of manufacture

6. NOTES

6.1 Intended use.- The pressure switches covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891, and operating with hydraulic fluid conforming to Specification MIL-H-8446 at pressures which do not exceed 4,000 psi. The pressure switch is further intended for use in a manifolded or packaged type system.

6.2 Ordering data.- Procurement documents should specify the following:

(a) Title, number, and date of this specification
(b) MS part number
(c) Federal stock number
(d) Class (and pressure setting if class 1)

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attentio of the suppliers is called to this requirement, and manufacturers are urged to arrang to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or

corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons

Air Force

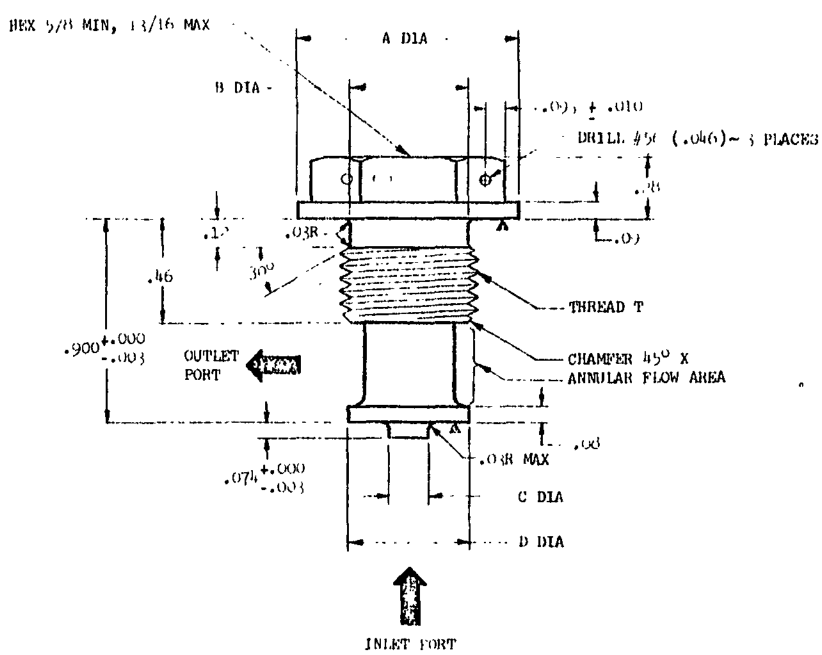
Preparing Activity:

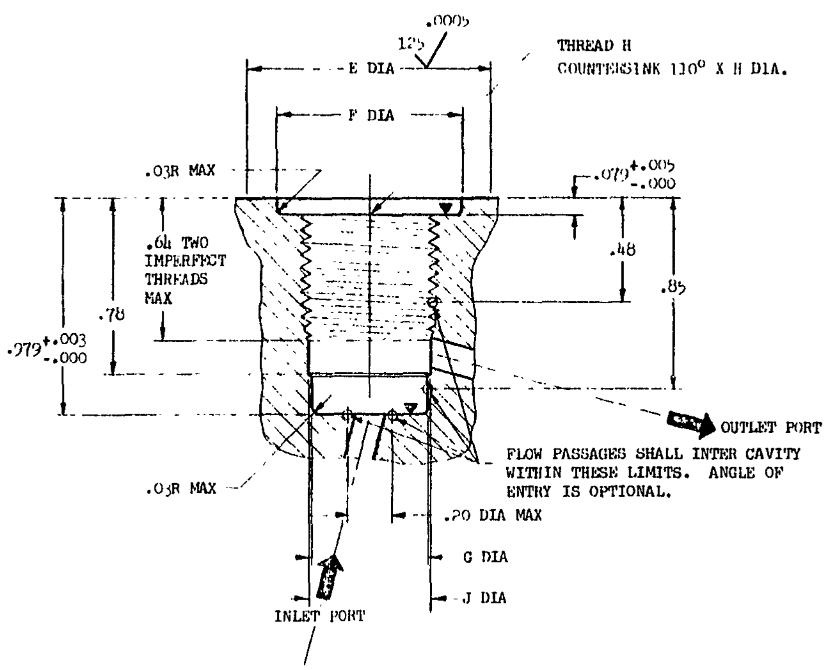
Navy - Bureau of Naval Weapons

APPENDIX IV

Suggested MIL Specification for Thermal Relief Valve
Suggested MS Standard for Thermal Relief Valve

FED. SUP CLASS





REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, THERMAL RELIEF** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

FED. SUP CLASS

PART NUMBER	THREAD "T"	A	B +.000 -.005	C +.000 -.001	D +.000 -.002	RATED FLOW GPM	PRESSURE RANGE PSI	WEIGHT MAX LBS
MS -1	5/8-18UNF-3A	1.00	.544	.188	.557	.10	1000-2100	.07
MS -2	11/16-24NEF-3A	1.06	.626	.219	.588	.10	2100-4100	.10
MS -3	13/16-20UNEF-3A	1.19	.740	.344	.713	.10	4100-5500	.18

CAVITY FOR PART NUMBER	THREAD "H"	E DIA	F DIA	G DIA +.002 -.000	J DIA
MS -1	5/8-18UNF-3B	1.10	$.843^{+.001}_{-.000}$	.562	$.5649^{+.0081}_{-.0000}$
MS -2	11/16-24NEF-3B	1.16	$.906^{+.001}_{-.000}$	.593	$.6424^{+.0070}_{-.0000}$
MS -3	13/16-20UNEF-3B	1.29	$1.031^{+.002}_{-.000}$	.718	$.7584^{+.0078}_{-.0000}$

DETAIL REQUIREMENTS

TEMPERATURE LIMITS - +450°F FLUID AND +650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE - OPERATING 4000 PSI, PROOF 6000, BURST 10,000 PSI
FLUID - SPECIFICATION MIL-H-8446.
SEALS - SPECIFICATION MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE.
PRESSURE DROP - ADJUSTABLE BETWEEN THESE LIMITS AT FLOW OF 0.10 GPM:

MS	-1	1000-2100 PSI
MS	-2	2100-4100 PSI
MS	-3	4100-5500 PSI

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16√ RHR. ALL OTHER SURFACES 125√ RHR UNLESS OTHERWISE NOTED.
TOLERANCES: THE SEALING SURFACES OF DIAMETERS "A" AND "D" SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THREAD "T" (AXIS) WITHIN .003 FIR. THE SEALING SURFACES OF DIAMETERS "F" AND "G" SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THREAD "H" (AXIS) WITHIN .003 FIR. SURFACE DEFINED BY "E" DIAMETER SHALL BE PERPENDICULAR TO THREAD "H" AXIS WITHIN .001R.
LINEAR TOLERANCE: ±.01 INCH UNLESS OTHERWISE NOTED.
ANGULAR TOLERANCE: ±2° UNLESS OTHERWISE NOTED.
THIS VALVE IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- . THE MS -1 IS NORMALLY USED IN A 1500 PSI SYSTEM; THE MS -2 IN A 3000 PSI SYSTEM; AND THE MS -3 IN A 4000 PSI SYSTEM.
SEALING SURFACES ARE DENOTED BY SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE MS PART NUMBER, THE WORDS, "THERMAL RELIEF VALVE", THE MANUFACTURER'S NAME OR TRADEMARK, AND THE MANUFACTURER'S PART NUMBER SHALL BE PERMANENTLY MARKED ON THE HEX AND/OR FLANGE SO THAT THE MARKING IS VISIBLE WHEN THE VALVE IS INSTALLED.

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE VALVE, THERMAL RELIEF 4,000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION
VALVE: AIRCRAFT HYDRAULIC THERMAL RELIEF

1. SCOPE

1.1 This specification covers cartridge-type, modular hydraulic, thermal expansion relief valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Thermal relief valves shall be of the following classes:

Class 1 - 1000 to 2100 psi (Pressure at 0.1 gpm flow)
Class 2 - 2100 to 4100 psi (Pressure at 0.1 gpm flow)
Class 3 - 4100 to 5500 psi (Pressure at 0.1 gpm flow)

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible, Waterproof
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection, Process, Magnetic Particle
MIL-H-6875	Heat Treatment of Steels, (Aircraft Practice) For
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III; Design, Installation, Tests and Data Requirements, General Specification for
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specifications and Standards, Use of
MS-33540	Safety Wiring - General Practices for
MS-20995	Wire-Lock

Drawing

MS-

2.2 Other publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification.- The thermal relief valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes.- Materials and processes used in the manufacture of these valves shall conform to the following requirements and to the applicable specifications as defined in Section 2.

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion during the normal service life of the valve which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency.

Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel.- Close-fitting, sliding, steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts.- Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts.- Standard parts selected in accordance with section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the manufacturer's drawings.

3.4 Design and construction.

3.4.1 Envelope.- The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification and MS- .

3.4.2 Hydraulic fluid.- The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range.- The valves shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F. There shall be no evidence of external leakage or chatter when tested per 4.6.3.3.

3.4.4 Threads.- Only class three, straight threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals.- Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety-wire shall be applied in accordance with standard drawings MS-33540 and MS-20995.

3.4.7 Retainer 'ings.- Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valves.

3.4.8 Structural strength.- The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight.- The weight shall be kept to a minimum consistent with good design, and shall be specified on the applicable drawing.

3.4.10 Mounting position.- The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control.- The valves shall be designed to pass rated flow per 1.2 from inlet port to outlet. Flow shall be checked or blocked from outlet to inlet ports.

3.4.12 Surface roughness.- Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's parts.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governedd by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another housing without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification.- Each valve shall [illegible] the identifying markings placed on the hex-head or the flange so that the identification can be read when the valve is installed in the manifold cavity. Each valve shall be permanently and legibly marked with the following information per MIL-H-7911.

Valve, Thermal Relief

MS-

Manufacturer's Part Number

Manufacturer's Name or Trademark

In addition, the pressure setting shall be stamped into a metal tag which is attached to the safety-wire securing the adjustment or adjustment cover.

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contamination. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection.- All magnetizable highly stressed parts shall be subjected to magnetic inspection per Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection per Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated flow and operating pressures.- Class 1, 2, and 3 valves rated flow and operating pressures shall be per Table I, when tested per 4.6.3. Rated flow pressures shall be the differential pressures measured across class 1, 2, and 3 valves when the valves are by-passing 0.1GPM.

3.8.2 Proof pressures.- Class 1, 2, and 3 valves proof pressures shall be per Table I and there shall be no evidence of external leakage, failure or permanent set when tested per 4.6.2.

3.8.3 Burst pressures.- Class 1, 2, and 3 valves burst pressures shall be per Table I and the valves shall not burst at any pressure below those specified when tested per 4.6.6.

TABLE I

THERMAL RELIEF VALVE RATED FLOW AND PRESSURES

THERMAL RELIEF VALVES	RATED FLOW GPM	HYDRAULIC SYS. RATED PRESSURE PSI	ADJUSTABLE PRESSURE SETTING RANGE		MIN. ALLOWABLE RESEAT PRESSURE, psi		OPERATING PRESSURE RANGE psi	PROOF PRESSURE psi	BURST PRESSURE MIN. psi
			MIN. psi	MAX. psi	AT MIN. psi SETTING	AT MAX. psi SETTING			
CLASS I VALVES	0.1	1,500	1,000	2,100	820	1,720	0-2,100	2,250	3,750
CLASS 2 VALVES	0.1	3,000	2,100	4,100	1720	3,360	0-4,100	4,500	7,500
CLASS 3 VALVES	0.1	4,000	4,100	5,500	3360	4,500	0-5,500	6,000	10,000

3.8.4 Pressure adjustment.- Class 1, 2, and 3 valves shall be adjustable to cover the pressure ranges specified in Table 1. Pressure adjustment screws shall be so designed and constructed that they may be locked to prevent loosening under vibration. The locking method shall be approved by the procuring activity. It shall be possible to adjust the locking device with a standard wrench or screw driver, when tested per 4.6.3.

3.8.5 Reverse flow.- Class 1, 2, and 3 valves shall have the flow checked or blocked in the reverse direction when tested per 4.6.2.

3.8.6 Static cracking pressures.- Static cracking pressures shall be the minimum pressures at which fluid is passed through class 1, 2, and 3 valves at the rate of 0.1 cc (approximately 2 drops) per minute during the application of increasing pressures supplied by a hand pump, when tested per 4.6.3.

3.8.7 Dynamic cracking pressures.- Dynamic cracking pressures shall be the minimum pressures at which fluid is passed through class 1, 2, and 3 valves at the rate of 5 cc(approximately 100drops) per minute during the application of increasing pressures supplied by a power-driven pump, when tested per 4.6.3.

3.8.8 Reseat pressures.- Reseat pressures shall be the pressures at which fluid is passed through class 1, 2, and 3 valves at a rate of 1.5 cc (approximately 30 drops) per minute during the application of decreasing pressures supplied by a power driven pump. The reseat pressures shall not be less than 82 percent of the rated flow pressure setting per Table I, when tested per 4.6.3.

3.8.9 Static leakage.- Static leakage rate for class 1, 2, and 3 valves shall not exceed 0.5 cc (approximately 10 drops) per hour, when tested per 4.6.3.

3.8.10 Dynamic leakage

3.8.10.1 Leakage during decreasing pressure.- The rate of internal leakage for class 1, 2, and 3 valves at any pressure below the reseat pressure, during decreasing pressure, shall not exceed 0.5 cc per minute, when tested per 4.6.3.

3.8.10.2 Leakage during increasing pressure.- The rate of internal leakage for class 1, 2, and 3 valves at any pressure below the cracking pressure, during increasing pressure, shall not exceed 0.5 cc per minute, when tested per 4.6.3.

3.8.11 Endurance.- After 10,000 cycles of operation, class 1, 2, and 3 valves static leakage rate shall not exceed 1.0 cc (approximately 20 drops) per hour and the dynamic leakage rate shall not exceed 1.0 cc(approximately 20 drops) per minute, when tested per 4.6.4.

3.8.12 Vibration.- Class 1, 2, and 3 valves shall be capable of satisfactory operation after being subjected to vibration varying between 5 and 2,000 cps, at an amplitude of 0.04 inch (0.08 inch total excursion) or 15 "g's" whichever is limiting. Static leakage shall not exceed 1.0 cc (approximately 20 drops) per hour and dynamic leakage shall not exceed 1.0 cc (approximately 20 drops) per minute, when tested per 4.6.5.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.- The manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests - The inspection and testing of thermal relief valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of thermal relief valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Qualification tests - The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

A. Examination of product per 4.6.1.

B. Proof Pressure per 4.6.2.

C. Static Leakage per 4.6.3.1

D. Dynamic Leakage and Flow per 4.6.3.2.

E. Extreme Temperature Operation per 4.6.3.3

F. Endurance per 4.6.4.

G. Vibration per 4.6.5.

H. Burst Pressure per 4.6.6.

4.4 Acceptance tests - Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

A. Examination of Product per 4.6.1

B. Proof Pressure per 4.6.2.

C. Static Leakage per 4.6.3.1.

4.5 Test conditions

4.5.1 Test fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature - If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination.- Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up

before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of particle	Percent by weight of total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	18 ± 3
over 40 micron	9 ± 3

4.5.4 Filtration.- The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity. The tes housing shall be acceptable to the procuring agency.

4.5.5.2 Acceptance test housing.- The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test methods.

4.6.1 Examination of product.- Each valve shall be carefully examined to determine conformance with the requirements of this specification for weight, workmanship, marking, conformance of dimensions to applicable drawings, and for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Proof pressure test.- After bleeding all air from the valve, and plugging the outlet port, a proof pressure of 2250 psi for the Class 1 valve, 4500 psi for the Class 2, and 6000 psi for the Class 3 valve shall be applied at the pressure port for at least 2 minutes. Rate of pressure application shall not exceed 25,000 psi per minute. Any evidence of external leakage, failure, or permanent set, shall be cause for rejection. This test shall be repeated with the pressure port open and pressure applied to the outlet port. The proof pressure test shall be performed at 95±15°F for acceptance tests and 450±15°F for qualification tests.

4.6.3 Valve setting.- The tests described herein, under Static leakage, Dynamic leakage and flow, and Extreme temperature operation shall be conducted with the valve adjusted to deliver rated flow at the minimum pressure setting indicated in Table I, and the setting shall remain unaltered throughout the series of tests. The valve shall then be adjusted to deliver rated flow at the maximum pressure setting indicated in Table I and the series of tests repeated. The adjustment of the valve shall remain unaltered throughout this series of tests. Static cracking, dynamic cracking and reseat pressures shall be determined for each rated flow pressure setting in conjunction with the above adjustments or during the performance of the static and dynamic leakage tests.

4.6.3.1 Static leakage.- The valve shall be adjusted to deliver rated flow at the minimum pressure setting indicated in Table I. Pressure shall be applied by means of a hand pump until cracking pressure is determined. This cracking pressure shall be recorded. Pressure shall then be reduced to zero. For qualification tests, pressure shall be applied to the valve beginning from a value of approximately 50% of the pressure setting to 95% of the cracking pressure in increments not exceeding 10% of the pressure setting. For acceptance tests, pressure shall be increased from zero pressure to 95% of cracking pressure without using increments. At each increment the pressure shall be maintained constant for at least eight minutes. The leakage rate, as noted during the final six minutes of each test, shall not exceed 0.5 cc (approximately 10 drops) per hour. A typical

installation for the static leakage test is indicated in Figure 1.

4.6.3.2 Dynamic leakage and flow.- Pressure shall be applied to the valve by means of a power-driven pump until cracking pressure is determined. This value shall be recorded. Pressure shall then be increased until rated flow is measured. At rated flow, pressure shall not be greater than specified in Table I. Pressure shall then be reduced until the reseating pressure is determined and this value shall not be less than the value listed in Table I. The valve shall reseat within two minutes after reseating pressure is reached. Pressure shall then be reduced in increments not exceeding 10% of the pressure setting to a value of approximately 50% of the valve setting. By-passing of fluid at any pressure below the reseating pressure during decreasing pressure shall not exceed 0.5 cc (approximately 10 drops) per minute. Pressure shall next be applied from a value of approximately 50% of the pressure setting to 95% of the cracking pressure just determined in increments not exceeding 10% of the pressure settings. At each increment, pressure shall be maintained constant for 3 minutes with the pump operating continuously. The internal leakage in the third minute shall be noted and shall be considered the rate of internal leakage. By-passing of fluid at any pressure below the dynamic cracking pressure during increasing pressure shall not exceed 0.5 cc (approximately 10 drops) per minute. There shall be no external leakage or chatter during these tests. A typical set-up for this test is shown in Figure 1.

4.6.3.3 Extreme temperature operation.

4.6.3.3.1 Low temperature and rapid warm-up.- The valve and fluid shall be soaked at -65°F for eight hours minimum. At the end of this period and with fluid at -65°F the rated flow pressure and reseat pressure shall be determined and recorded. The valve shall then be allowed to warm up rapidly to -20°F and with the fluid temperature held at -20°F the rated flow pressure and reseat

pressure shall be determined. The reseat pressure shall not be less than the value specified in Table I. The valve shall then be allowed to warm up rapidly and a minimum of five checks for static cracking pressure and reseating pressure shall be conducted at approximately equal intervals before the valve warms up to room temperature. The reseat pressure shall not be less than the value specified in Table I. Rated flow pressure shall be checked at room temperature (95±15°F) and shall not exceed the limits listed in Table I. There shall be no evidence of external leakage or chatter during these tests.

4.6.3.3.2 High temperature operation.- The temperature of the valve and fluid shall be stabilized at 450°F. The test for Dynamic leakage and flow (paragraph 4.6.3.2) shall then be conducted at this temperature. Operation shall be within the limits specified for dynamic leakage and flow at normal temperature. Leakage may be measured by noting a fluid level change through a sight glass.

4.6.4 Endurance.- A typical set-up for the endurance test is shown in Figure 2. The endurance test shall be conducted while the valve undergoes a time-temperature spectrum as shown in Figure 3. This spectrum shall be repeated two times. The valve shall be cycled during this test by increasing pressure to produce rated flow at the maximum pressure setting specified in Table I, and decreasing pressure to 60%, or less, of this pressure setting for 10,000 cycles. The rate of cycling shall be approximately 13 cycles per minute. After completion of the endurance cycling and with the valve setting unchanged, static and dynamic leakage shall be determined (paragraphs 4.6.3.1 and 4.6.3.2). Static leakage shall not exceed 1.0 cc (approximately 20 drops) per hour. Dynamic leakage shall not exceed 1.0 cc (approximately 20 drops) per minute.

4.6.5 Vibration test

a. If friction locking type adjustment screws are utilized in the valve design, such adjustment screws shall be adjusted through full range 15 times prior to starting the vibration tests. With the valve set at the maximum setting specified in Table I, it shall be checked for rated flow pressure and reseat pressure and shall be within the limit specified in Table I. These values shall be recorded.

b. With the fluid temperature maintained at 95±15°F the valve shall be opened to produce rated flow at maximum pressure setting specified in Table I, and then closed under a 60% reduction in pressure. The rate of cycling shall be between 10 and 20 cycles per minute. While the valve is being cycled in this manner it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2000 cps in 30 minutes. The amplitude shall be .04 inch (.08 inch total excursion) or 15G whichever is limiting. This test shall be repeated two times and during this time the frequency of any and all resonant points shall be noted. Vibrate the valve for 90 minutes at the most severe resonant frequency noted above at .08 inch total excursion or 15G whichever is less severe. If no resonant frequency is found the valve shall be vibrated at 500 cps for 90 minutes. After completion of the 90 minutes, the valve shall be checked for reseat pressure while the valve is vibrating at a frequency equal to the most severe resonant frequency plus 10% and again at a frequency equal to the most severe resonant frequency minus 10%. The reseat pressure shall not be less than the reseating pressure limit specified in Table I.

c. Repeat (b) changing the direction of vibration 90° horizontally.

d. Repeat (b) changing the direction of vibration to vertical.

e. After completion of (b), (c), and (d) the valve shall be checked for rated flow pressure and reseat pressure and these values shall be within the range specified in Table I. Static and dynamic leakage shall also be determined

(reference 4.6.3.1 and 4.6.3.2). Static leakage shall not exceed 1.0 cc (approximately 20 drops) per hour. Dynamic leakage shall not exceed 1.0 cc (approximately 20 drops) per minute.

f. The valve shall then be removed from the manifold and visually insrected for any mechanical failures.

4.6.6 Burst pressure.- Pressure shall be applied to the pressure port with outlet port plugged. The pressure shall be applied at a rate not exceeding 25,000 psi per minite until a pressure of 3,750 psi is reached on the Class 1 valve, 7,500 on the Class 2 valve and 10,000 psi on a Class 3 valve. The valve shall withstand the specified pressure for 2 minutes without rupture. Fluid temperature shall be 95±15°F for this test. This test shall be repeated with the pressure port plugged and pressure applied to the checked flow port.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging.- Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments.- Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document
Name of part
MS part no.
Month and year of manufacture
Class or size

6. NOTES

6.1 Intended use.- The thermal relief valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891 and operating with hydraulic fluid conforming to Specification MIL-H-8446. The valve is further intended for use in a manifolded or packaged type syste

6.2 Ordering data - Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number

(c) Class

(d) Federal stock number

(e) Pressure setting

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

Preparing activity:

Navy - Bureau of Naval Weapons

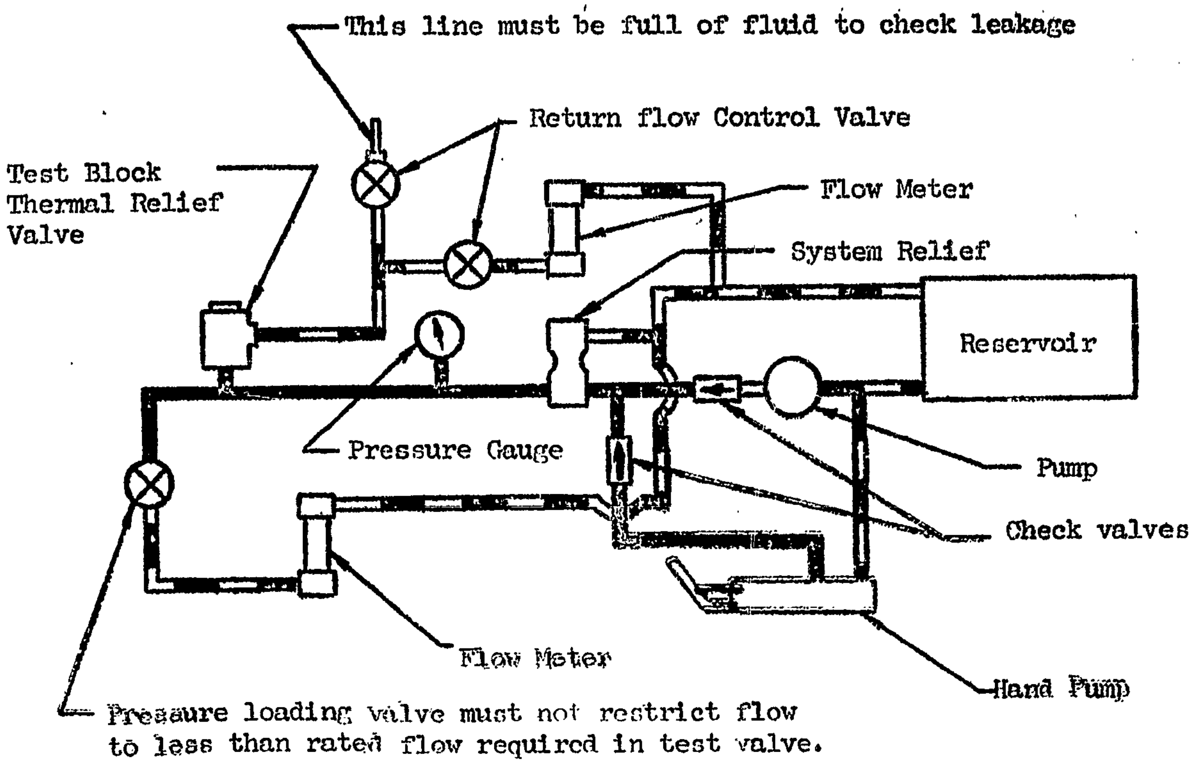


FIGURE 1

Typical Set-up for Dynamic Leakage and Flow Test

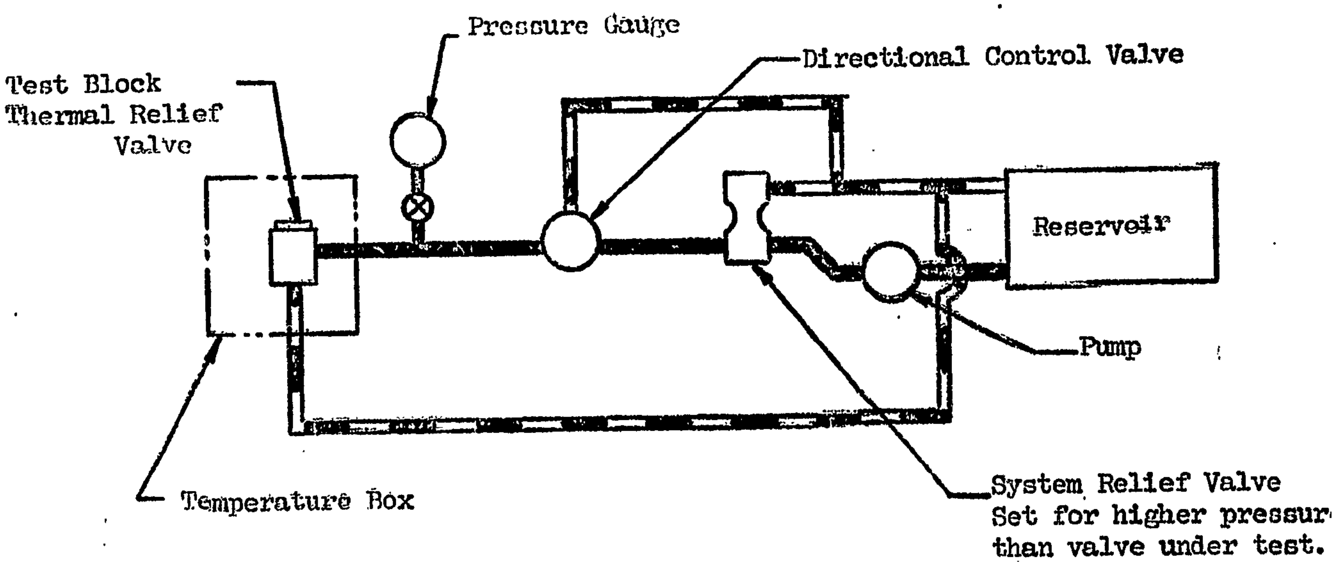


FIGURE 2
Typical Set-Up for Endurance Test

NOTES:

1. Rate of temperature rise or decay may vary within the shaded area shown.

2. Six and one half hours of endurance cycling are to be run in one day. Components are to be soaked 8 hours or overnight at the low temperature required to start the following day of testing.

3. The ambient temperature shall be maintained between 450 - 650°F during the time from the 2nd hour through the 5th hour of the spectrum shown.

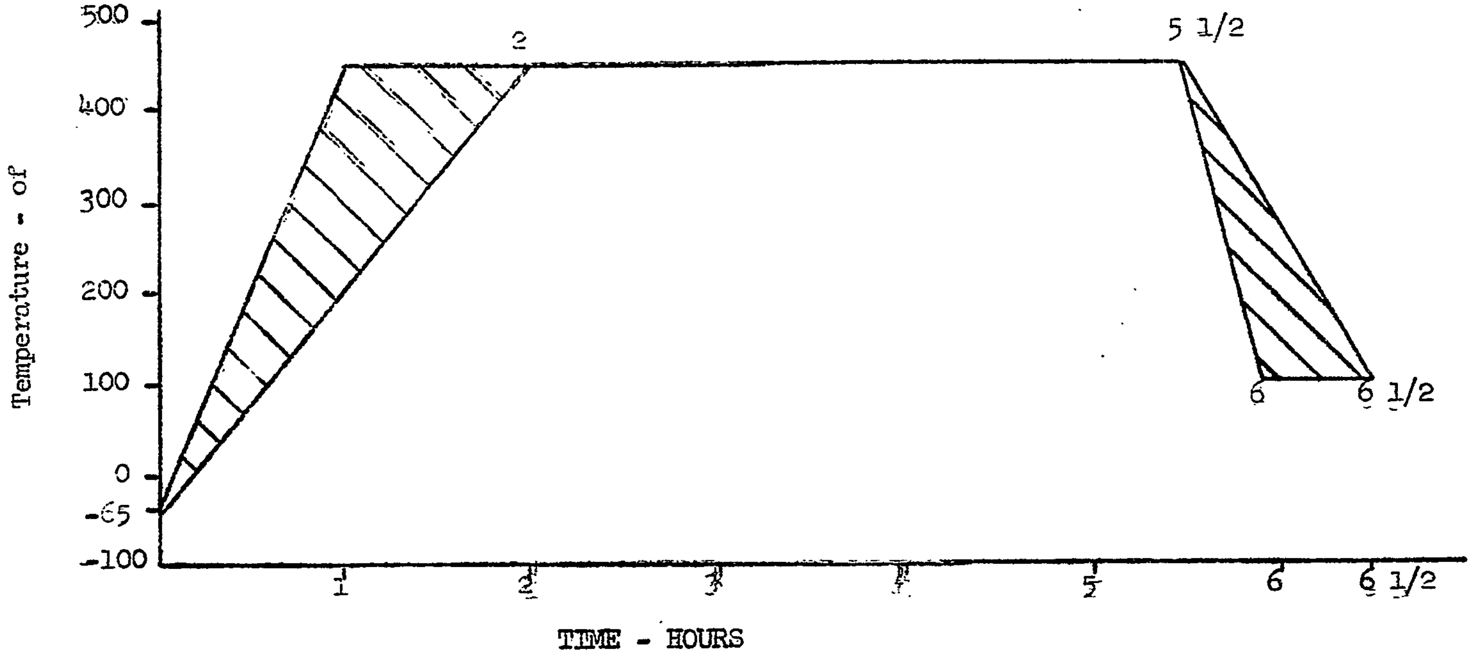
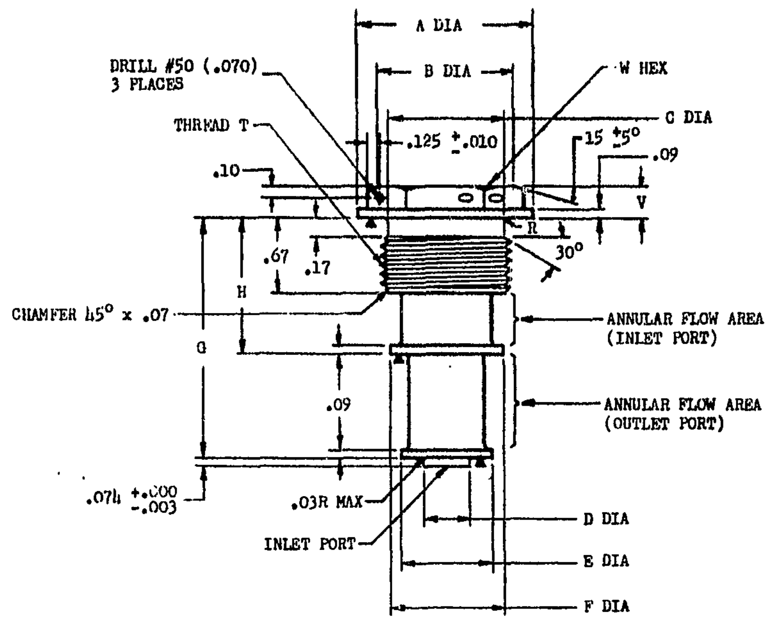
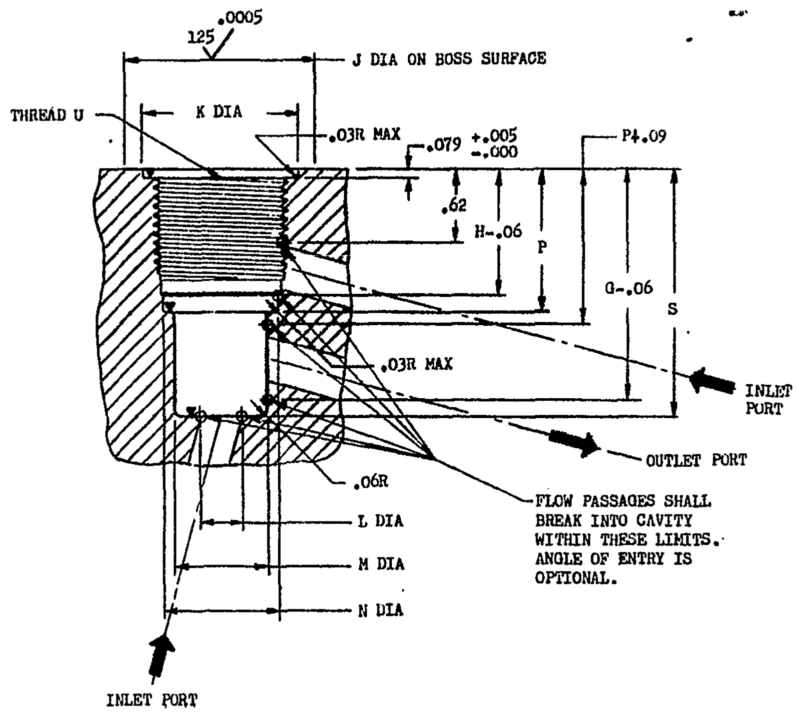


FIGURE 3

APPENDIX V

Suggested MIL Specification for Shuttle Valve
Suggested MS Standard for Shuttle Valve





REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC SHUTTLE** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

FED. SUP CLASS

TABLE FOR SHUTTLE VALVES

PART NUMBER	THREAD T	A DIA	B DIA	C DIA +.000 -.005	D DIA +.000 -.001	E DIA	F DIA +.000 -.002	G +.000 -.003	H +.000 -.003	R	V
MS -1	1 13/16-12UN-3A	1.59	1.25	1.068	.406	.84	1.057	2.145	1.200	.04	.30
MS -2	1 7/16-12UN-3A	1.84	1.50	1.318	.656	1.03	1.245	2.765	1.380	.04	.32
MS -3	1 3/4-12UN-3A	2.16	1.69	1.633	.813	1.28	1.495	3.340	1.620	.05	.34

PART NUMBER	W HEX	RATED FLOW	WEIGHT MAX
MS -1	$1.250^{+.000}_{-.038}$	4 GPM	.49 LBS
MS -2	$1.500^{+.000}_{-.050}$	12 GPM	.74 LBS
MS -3	$1.687^{+.000}_{-.056}$	25 GPM	1.06 LBS.

TABLE FOR VALVE CAVITIES

CAVITY FOR	THREAD U	J DIA MIN	K DIA	L DIA MAX	M DIA	N DIA +.002 -.000	H +.000 -.003	P +.003 -.000	G +.000 -.003	S +.003 -.000
MS -1	1 3/16-12UN-3B	1.65	$1.437^{+.002}_{-.000}$	.396	.86	1.062	1.200	1.279	2.145	2.224
MS -2	1 7/16-12UN-3B	1.90	$1.687^{+.002}_{-.000}$	.646	1.05	1.250	1.380	1.459	2.765	2.844
MS -3	1 3/4-12UN-3B	2.22	$2.000^{+.003}_{-.000}$	.803	$1.30^{+.01}_{-.00}$	1.500	1.620	1.699	3.340	3.419

DETAIL REQUIREMENTS

TEMPERATURE LIMITS	-	+450°F FLUID AND +650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE	-	OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI.
FLUID	-	SPECIFICATION MIL-H-8446.
SEALS	-	SPECIFICATION MIL-
LIFE	-	SEE SPECIFICATION MIL- FOR ENDURANCE.
PRESSURE DROP	-	NOT TO EXCEED 25 PSI AT RATED FLOW.

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16/ RHR OR LESS. ALL OTHER SURFACES SHALL BE 125/ RHR MAXIMUM UNLESS OTHERWISE NOTED.

TOLERANCES: THE THREE SEALING SURFACES ON THE VALVE SHALL BE PARALLEL WITHIN .002 FIR AND PERPENDICULAR TO AXIS OF VALVE THREAD WITHIN .003 FIR. THE THREE SEALING SURFACES OF THE CAVITY SHALL BE PARALLEL WITHIN .002 FIR AND PERPENDICULAR TO THE AXIS OF THE CAVITY THREAD WITHIN .003 FIR.
LINEAR TOLERANCE: ±.01 INCH UNLESS OTHERWISE NOTED.
ANGULAR TOLERANCE: ±2° UNLESS OTHERWISE NOTED.
THIS VALVE IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI, TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- .
SEAL SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE MS PART NUMBER, THE WORDS "SHUTTLE VALVE", THE MANUFACTURER'S NAME OR TRADEMARK AND THE MANUFACTURER'S PART NUMBER SHALL BE PERMANENTLY MARKED ON THE HEX HEAD OR THE FLANGE SURFACES SO THAT THE MARKING IS VISIBLE WHEN THE VALVE IS INSTALLED.

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC SHUTTLE** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION
VALVES: AIRCRAFT HYDRAULIC SHUTTLE

1. SCOPE

1.1 Scope.- This specification covers cartridge-type modular hydraulic shuttle valves for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Shuttle valves shall be of the following classes:

Class 1 - 0 to 4 gallons per minute capacity

Class 2 - 0 to 12 gallons per minute capacity

Class 3 - 0 to 25 gallons per minute capacity

2. APPLICABLE DOCUEMTNS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproofed, Flexible Waterproofed
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection Process, Magnetic Particle
MIL-H-6875	Heat Treatment of Steels (Aircraft Practice) Process for
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-M-7911	Marking, Identification of Aeronautical Equipment, Assemblies and Parts
MIL-H-8446	Hydraulic Fluid, Non-petroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III, Design, Installation, Tests and Data Requirements, Aircraft, General Specification For
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Specifications and Standards, Use of
MS-33540	Safety Wiring, General Practices For
MS-20995	Wire-Lock

Drawings

MS -	Shuttle Valve, Modular, Envelope For

2.2 Other publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in the order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification.- The shuttle valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes.- Materials and processes used in the manufacture of these valves shall conform to the following requirements and to applicable specifications as defined in Section 2:

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion resisting type or shall be adequately protected to resist corrosion during the normal service life of the valve which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency. Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel.- Close-fitting, sliding steel parts shall be cold stabilized in accordance with specification MIL-H-6875B to reduce warpage tendencies.

3.2.3 Plastic parts.- Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts.- Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the contractor's drawings.

3.4 Design and construction

3.4.1 Envelope.- The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification, MS_________ and applicable drawings.

3.4.2 Hydraulic fluid.- The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range.- The valves shall be designed to meet the functional and operational requirements of this specification throughout a range of -65°F to 450°F fluid temperature and -65°F to 650°F ambient temperature.

3.4.4 Threads.- Only class 3 threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals.- Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with Standard Drawings MS-33540 and MS-20995.

3.4.7 Retainer rings.- Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valve.

3.4.8 Structural strength.- The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight.- The weight shall be kept to a minimum consistent with good design, and shall be as specified on the applicable drawing.

3.4.10 Mounting position.- The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control.- The valves shall be designed to pass rated flow per 1.2 from either inlet port to a common outlet port and from outlet port to either inlet port.

3.4.12 Surface roughness.- Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's parts.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327.

Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification.- Each valve shall have the identifying markings placed on the hex head or the flange so that the identification can be read when the valve is installed in a manifold cavity. Each valve shall be permanently and legibly marked with the following information, per MIL-M-7911.

Valve, Shuttle

MS No.

Manufacturer's Part no.

Manufacturer's Name or Trademark

In addition, the pressure setting shall be stamped into a metal tag which is attached to the safety wire securing the adjustment or adjustment cover.

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contaminant. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection.- All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection

shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated pressure.- The valves shall be designed to operate satisfactorily in a hydraulic system having a rated pressure of 4,000 psi, when tested per 4.6.3.

3.8.2 Operating pressure.- The valves shall be designed to insure satisfactory operation and service life throughout the operating range of 0 to 4,000 psi, when tested per 4.6.3. The values shall be capable of operation at 6,000 psi.

3.8.3 Proof pressure.- The valves shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.2.

3.8.4 Burst pressure.- The valves shall be designed so as not to burst at any pressure below 10,000 psi, when tested per 4.6.12.

3.8.5 Leakage and shuttling with fluid

3.8.5.1 Qualification

a. Shuttling pressure range - The fluid pressure range at which the valves shuttle shall not be less than 25 psi nor more than 100 psi, when tested per 4.6.3.1.

b. Dynamic leakage during shuttling - The internal leakage of the valves during a single shuttle operation shall not exceed 3cc, when tested per 4.6.3.1.

c. Static leakage after acutation - The internal static leakage of the valves shall not exceed 1/4 cc at 5 psi and there shall be no leakage at 4,000 psi, when tested per 4.6.3.1.

d. External leakage - The valves shall show no evidence of external leakage, when tested per 4.6.3.1.

3.8.5.2 Acceptance - The valves shall meet the requirements of paragraph 3.8.5.1, except that the static leakage of the valves at 5 psi shall not exceed one drop, when tested per 4.6.3.2.

3.8.6 Air pressure shuttling and Leakage

3.8.6.1 Dynamic leakage.- The internal air leakage through a single shuttle operation of the valves shall not exceed 3 cc at 100 psi, when tested per 4.6.4.

3.8.6.2 Static Leakage.- The internal air leakage of the valves shall not exceed 10 cubic inches at 15 psi and at 4,000 psi, when tested per 4.6.4.

3.8.7 Extreme temperature performance.

3.8.7.1 Low temperature - The valves shall meet the requirements of paragraph 3.8.5.2, when tested per 4.6.5.1.

3.8.7.2 Rapid warm-up.- The valves shall meet the requirements of paragraph 3.8.5.2 during rapid warm-up, when tested per 4.6.5.2.

3.8.7.3 High temperature functioning.- The valves shall meet the requirements of paragraph 3.8.5.2, when tested per 4.6.5.3.

3.8.8 Impulse cycling.- The valves shall meet the requirements of paragraph 3.8.5.2 after 15,000 high temperature impulse cycles at 35±5 cpm

and after 5,000 intermediate temperature cycles at 35±5 cpm, when tested per 4.6.6. In addition, during the test the internal leakage shall not exceed 2 cc for each 100 impulse cycles and there shall be no measurable external leakage.

3.8.9 Endurance cycling.- The valves shall meet the requirements of paragraph 3.8.5.2 after being subjected to 2,000 cycles of shuttling at 5 to 6 cpm, when tested per 4.6.7, except that internal static leakage at 5 psi shall not exceed 3 drops.

3.8.10 Shuttling against a closed line.- The pressure drop of the valves from inlet through outlet shall not exceed 25 psi after shuttling against a closed line, when tested per 4.6.8.

3.8.11 Surge flow shuttling.- The valves shall show no evidence of malfunctioning or damage after 20 cycles of 4,000 psi surge-flow shuttling, when tested per 4.6.9.

3.8.12 Pressure drop of the valves without housings.- The pressure drop of the valves without housings shall not exceed 25 psi in both directions, when tested per 4.6.10. The pressure drop for the valve module only shall be the difference in the pressure drop for the valve correctly installed in the test housing and the pressure drop for the housing with the valve removed and the corresponding cavity plugged.

3.8.13 Vibration.- The valves shall be capable of withstanding vibrations from 5 to 2,000 cps with an amplitude of 0.04 inch (0.08 inch total excursion) or 15 g, whichever is limiting, along three mutually perpendicular axes, when tested per 4.6.11. After the test, the valves shall meet the requirements of

paragraph 3.8.5.2, except that the internal static leakage rate shall not exceed 3 drops.

3.8.14 Reverse flow unseating.- During reverse flow, the valves shall not unseat and the internal leakage shall not exceed 10 drops per minute, when tested per 4.6.13.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.- The manufacturer is responsible for the performance of all acceptance tests prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests.- The inspection and testing of shuttle valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of shuttle valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Tests.- The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2.

(c) Leakage and shuttling with fluid per 4.6.3.

(d) Reverse flow unseating per 4.6.13.

(e) Air pressure shuttling and leakage per 4.6.4.

(f) Extreme temperature performance per 4.6.5.

(g) Impulse cycling per 4.6.6.

(h) Endurance per 4.6.7.

(i) Shuttling against a closed line per 4.6.8.

(j) Surge flow shuttling per 4.6.9.

(k) Pressure drop per 4.6.10.

(l) Vibration per 4.6.11.

(m) Burst pressure per 4.6.12.

4.4 Acceptance tests.- Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2.

(c) Leakage and shuttling with fluid per 4.6.3.

(d) Reverse flow unseating per 4.6.13.

4.5 Test conditions

4.5.1 Test fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95±15° for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination.- Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of Particle	Percent by Weight of Total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	18 ± 3
over 40 micron	9 ± 3

4.5.4 Filtration.- The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity and which is acceptable to the procuring agency.

4.5.5.2 Acceptance test housing.- The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test methods.

4.6.1 Examination of product.- Each valve shall be carefully examined to determine conformance with the requirements of this specification for workmanship, marking, conformance to applicable drawings, or for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ± 5 micro-inches at the level being measured.

4.6.2 Proof pressure test.- Pressure shall be applied to each inlet port while the opposite inlet port is open to the atmosphere, at a rate not exceeding 25,000 psi per minute until [illegible],000 psi is reached. This proof pressure shall be held for at least two minutes, and there shall be no evidence of leakage, permanent set, or other damage. The shuttle valve shall be filled with fluid and stabilized at 450±15°F for qualification test only. For acceptance tests, proof pressure tests shall be conducted at 95±15°F.

4.6.3 Leakage and shuttling with fluid.

4.6.3.1 Qualification Test for Leakage and Shuttling With Fluid.- This test shall be performed with a test set-up similar to Figure 1. This test shall be conducted with a fluid temperature of 95±15°F. The outlet port shall be

plugged, and the valve so positioned that the unconnected inlet port is down and open to the atmosphere. With the system bled of air, the pump and needle valve shall be operated until the valve shuttles at a flow rate not exceeding 10 cubic inches per minute. Leakage through a single shuttling operation shall not exceed 3 cc. The pressure for shuttling shall be observed and shall be not less than 25 psi, nor greater than 100 psi. A pressure of 5 psi shall then be applied to the valve for a period of 32 minutes. Leakage in a 30 minute period, following a 2 minute seating period, shall not exceed 1/4 cc. The pressure shall then be raised to 4000 psi and there shall be no leakage in a 30 minute period following a two minute seating time. The above test shall be repeated with the inlet ports interchanged. There shall be no evidence of external leakage.

4.6.3.2 Acceptance test for leakage and shuttling with fluid.- This shall be conducted with a test set-up similar to Figure 1. The test block shall be so positioned, with the outlet port plugged, that the unconnected inlet port is down and open to the atmosphere. Then with the system bled of air, the pump and needle valve shall be operated until the valve shuttles at a flow rate not exceeding 10 cubic inches per minute. Leakage through a single shuttle operation shall not exceed 3 cc. The shuttling pressure shall be observed and shall be not less than 25 psi, nor greater than 100 psi. A pressure of 5 psi shall then be applied to the valve for a period of 8 minutes, and the leakage observed during the final 6 minutes (after a 2 minute seating period) shall not exceed one drop. The pressure shall be raised to rated pressure, and there shall be no leakage when measured over a period of not less than 5 minutes. The leakage measurement period shall begin 3 minutes after application of the pressure, to allow the valve to seat. The valve shall also meet the above test requirements with the inlet ports interchanged. The fluid temperature shall be 95°±15°F. There shall

be no evidence of external leakage from the valve.

4.6.4 Air pressure shuttling and leakage.- This test shall be performed at a temperature of 95±15°F. The set-up shall be as shown in Figure 2. The shuttle valve shall be wet internally, but not filled with hydraulic fluid. With the air pressure reducing valve set at 100 psi, and shut off valve "A" closed, the quick-opening type valve "B" shall be opened, and the valve shall shuttle satisfactorily. Leakage of air past the shuttle valve piston, as collected in the graduate, shall not exceed 10 cubic inches of free air per shuttling cycle. Without further shuttling, the air pressure shall then be adjusted to 15 psi, and the leakage shall not exceed 10 cubic inches of free air per minute. Pressure shall then be raised to 4000 psi, and the leakage shall not exceed 10 cubic inches of free air per minute. Nitrogen may be used in place of air if desired. This test shall be repeated with air pressure applied to the other inlet port.

4.6.5 Extreme temperature performance.

4.6.5.1 Low-temperature functioning.- With a test set-up similar to Figure 3, the temperature shall be maintained at not warmer than -65°F for a soaking period of 4 hours. After this period, the valve shall be shuttled at least five times by means of the hand pump. After the fifth actuation, the shuttling pressure and leakage shall then be observed and recorded. This test shall be repeated with the temperature not warmer than -20°F. The shuttling pressure and leakage shall be as specified in 4.6.3.2. The shuttle may be manually reset between pressure shuttlings.

4.6.5.2 Rapid warm-up.- The low temperature test set-up shall be allowed to warm-up rapidly to a temperature of 450°F. While the temperature is being raised and without waiting for the temperature to stabilize throughout the set-up, the valve shall be shuttled at approximately 85°F increments of ambient temperature, and the shuttling pressure and leakage (internal) shall be as specified in 4.6.3.2 titled Leakage and Shuttling With Fluid.

4.6.5.3 High temperature functioning.- With a test set-up similar to Figure 3, the shuttle valve shall be subjected to an oil and ambient temperature of 450°F. The valve shall then be shuttled at least five times by means of a hand pump. After the fifth actuation, the shuttling pressure and leakage shall then be observed and shall be as specified in 4.6.3.2 titled "Leakage and Shuttling with Fluid."

4.6.6 Impulse cycling.- With a set-up similar to Figure 4, the shuttle valve shall be subjected to a total of 20,000 pressure cycles at a rate of 35±5 cpm. For each cycle, the directional control valve shall alternately apply rated pressure and then a pressure of 75 psi maximum to the inlet port nearest the hex head of the shuttle valve. Of the total number of cycles, 15,000 shall be performed in accordance with the procedure outlined in 4.4.6.1 titl "Impulse at High Temperature." The balance of 5,000 cycles shall be performed in accordance with the procedure outlined in 4.4.6.2 titled "Impulse at Intermediate Temperature." Surge pressure during the pressure build-up portion of each cycle shall be 6,000 psi. During this impulse cycling, internal leakage shall be collected at the unconnected inlet port and shall not exceed 2 cc per 100 cycles, and there shall be no measurable external leakage.

4.6.6.1 Impulse at high temperature.- The valve and hydraulic fluid of the test set-up shall be stabilized at a temperature of 450°F. The valve shall then be subjected to 15,000 cycles of impulse. The temperature of the valve shall then be reduced to a range of 95±15°F and the test specified in 4.6.3.2 titled Leakage and Shuttling With Fluid, shall then be conducted, and the requirement therein shall be satisfied.

4.6.6.2 Impulse at intermediate temperature.- The valve shall then be subjected to 5,000 cycles of impulse at a temperature of 275°F. The temperature of the test set-up shall then be reduced to a range of 95±15°F.

The test of 4.6.3.2 titled Leakage and Shuttling With Fluid, shall then be conducted, and the requirements therein shall be satisfied.

4.6.7 Endurance cycling.- With a test set-up similar to Figure 5, the shuttle valve shall be subjected to a total of 2,000 cycles of shuttling at a rate of 5 to 6 cpm. Shuttling shall be accomplished by operating the directional control valve in such manner as to alternately apply rated pressure to each inlet port. Surge pressures during the pressure application portion of each cycle shall be 6,000±300 psi. The endurance test shall be conducted while the valve undergoes a time-temperature spectrum as shown in Figure 6. The entire 2,000 cycles shall be completed in one spectrum. After the spectrum, the temperature of the test set-up shall be reduced to 95±15°F, at which the requirement for Leakage and shuttling with fluid 4.6.3.2 shall be checked and satisfied, except that the maximum allowable leakage shall be 3 drops. The temperature shall then be

reduced to -20°F and leakage and shuttling with fluid (4.6.3.2) again checked and satisfied except that the leakage during the final six minutes after a 2 minute seating period shall not exceed 3 drops.

4.6.8 Shuttling against a closed line.- This test shall be performed at a temperature of 95°±15°F. The valve shall be set-up as shown in Figure 7. With shutoff valve "B" and "C" closed, and shutoff valve "A" open, rated flow shall be directed through the flowmeter until air is thoroughly bled from the system. Shut-off valve "A" shall be then positively closed after which the 4-way valve shall be reversed from the position shown, in order to direct flow to the other inlet port of the test block. The pressure drop from inlet through outlet shall not exceed 25 psi. Five seconds shall be allowed before pressure drop reading is taken. This test shall be repeated 20 times.

4.6.9 Surge-flow shuttling.- The surge flow test shall be performed at a temperature of 95°±15°F. The valve shall be set up as shown in Figure 7, with shut-off valves "A", "B" and "C open. The 4-way valve, however, shall be put in a neutral position to permit the build-up to 4000 psi hydraulic pressure in the accumulator. The 4-way valve shall then be cycled 20 times. At the end of each shuttling operation or half cycle, the 4-way valve shall be returned to the neutral position to again permit the buildup of 4000 psi hydraulic pressure in the accumulator. There shall be no malfunctioning of or damage to the valve during this test.

4.6.10 Pressure rop.- This test shall be performed at a fluid temperature of 95±15°F Hydraulic pressure sufficient to produce rated flow shall be applied to either of the two inlets, first in the normal flow direction (from inlet to outlet) and then in the reverse direction

(from outlet to the same inlet port). This procedure shall then be repeated starting with the opposite inlet. Pressure and rate of flow shall be accurately maintained. A manometer, or suitable pressure gage, connected across the shuttle valve shall be used for accurate measurement of the pressure drop. Pressure drop in both directions shall be measured and shall not exceed 25 psi for the module only. The pressure drop for the module shall be determined by taking the difference in the pressure drop for the valve and test housing and the pressure drop for the housing as measured with the valve removed and the cavity plugged.

4.6.11 Vibration test.- With the fluid temperature maintained at 95±15°F, the valve shall be shuttled at a rate of 15 to 20 cpm. Shuttling shall be accomplished by applying rated pressure alternately to the inlet ports. While the valve is being shuttled, it shall be vibrated in a horizontal direction with the frequency with the frequency varying between 5 and 2000 cps in 30 minutes. The amplitude shall be .04 inches (.08 inch total excursion) or 15G, whichever is limiting. This test should be repeated two times and during this time, the frequency of any and all resonant points shall be noted. Vibrate the valve for 90 minutes at the most severe resonant frequency noted above at .08 in total excursion or 15G whichever is less severe. If no resonant frequency is found the valve shall be vibrated for 90 minutes at 500 cps. The above procedure shall be repeated with the direction of vibration changed 90° horizontally, and again with the direction of vibration changed to vertical. After completion of the vibration test, the valve shall be checked per paragraph 4.6.3.2, except that the allowable leakage shall be three (3) drops in the six (6) minute period. The valve shall then be removed from the manifold and visually inspected for any mechanical failures.

4.6.12 Burst pressure test.- With the outlet port plugged, pressure shall be applied to the inlet port until 10,000 psi is reached. This pressure shall be held for 2 minutes. There shall be no rupture of external or internal parts. This test shall be repeated with pressure applied to the other inlet port. The fluid temperature shall be 95±15°F for this test.

4.6.13 Reverse flow unseating.- Three times the rated flow of the valve shall be applied in a direction from the outlet port discharging through the open inlet port. During the test, the shuttle shall not unseat, and the leakage out of the opposite inlet port shall not exceed 10 drops per minute.

5. PREPARATION FOR DELIVERY

5.1 Preservation and Packaging.- Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A greaseproof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments.- Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document.

Name of part.

MS Part No.

Month and year of manufacture

Class or size

6. NOTES

6.1 Intended use.- The shuttle valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891, and operating with hydraulic fluid conforming to Specification MIL-H-8446 at pressures which do not exceed 4,000 psi. The shuttle valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering data.- Procurement documents should specify the following:

(a) Title, number and date of this specification.

(b) MS part number

(c) Class

(d) Federal stock number

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C.; however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons

Air Force

Preparing activity:

Navy - Bureau of Naval Weapons

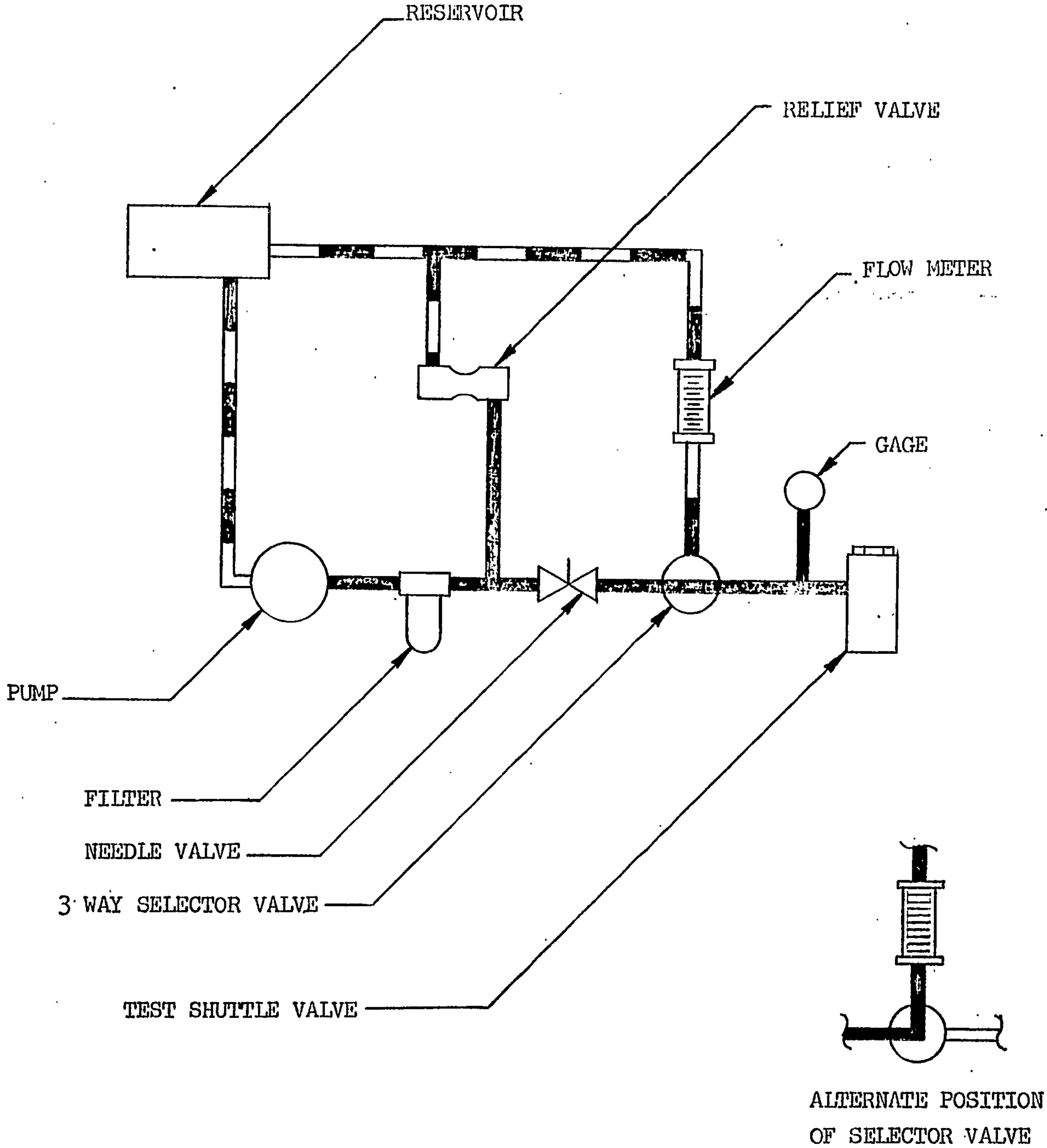


FIGURE 1

SET UP FOR LEAKAGE AND SHUTTLING WITH FLUID TEST

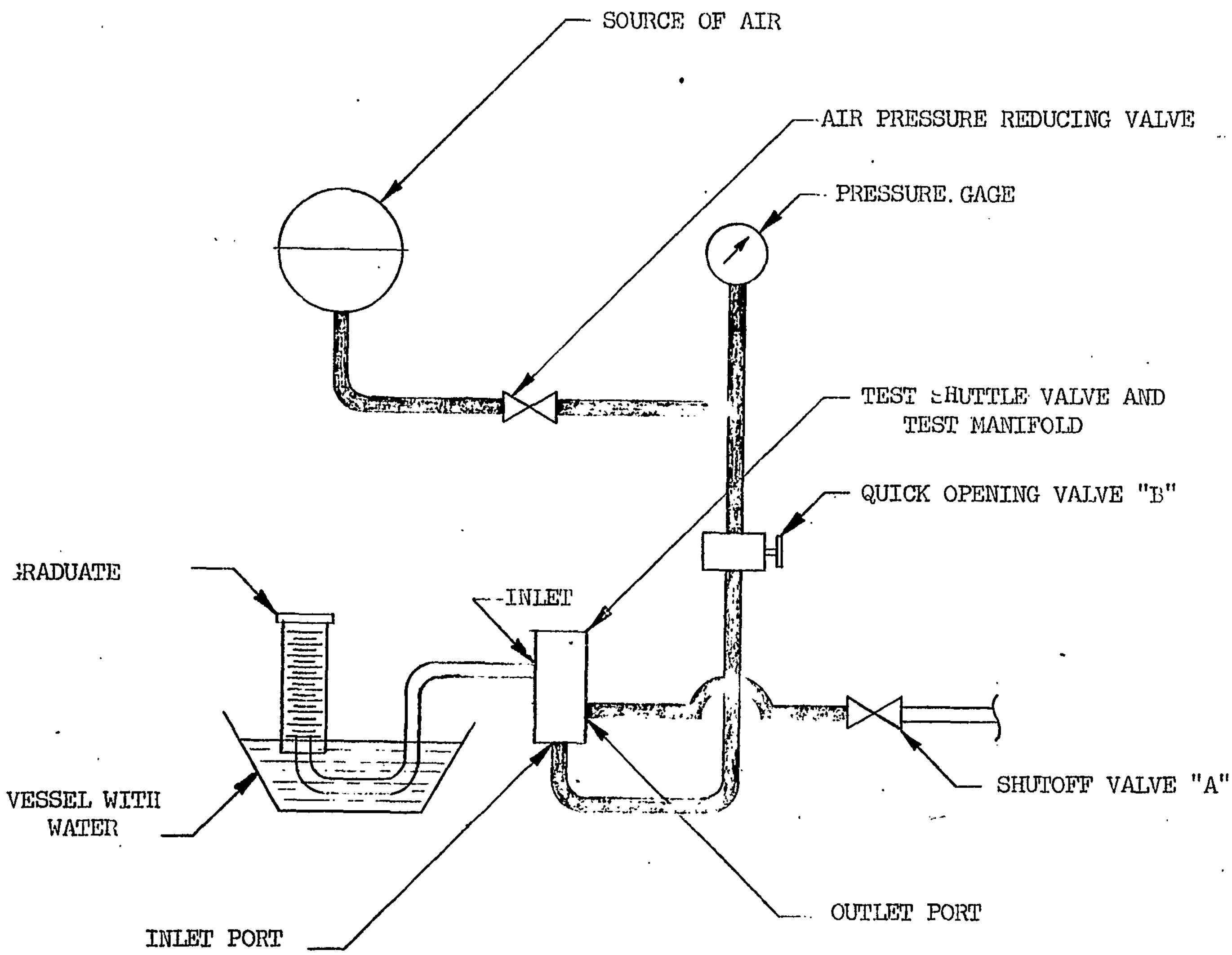


FIGURE 2

AIR PRESSURE SHUTTLE AND LEAKAGE TEST

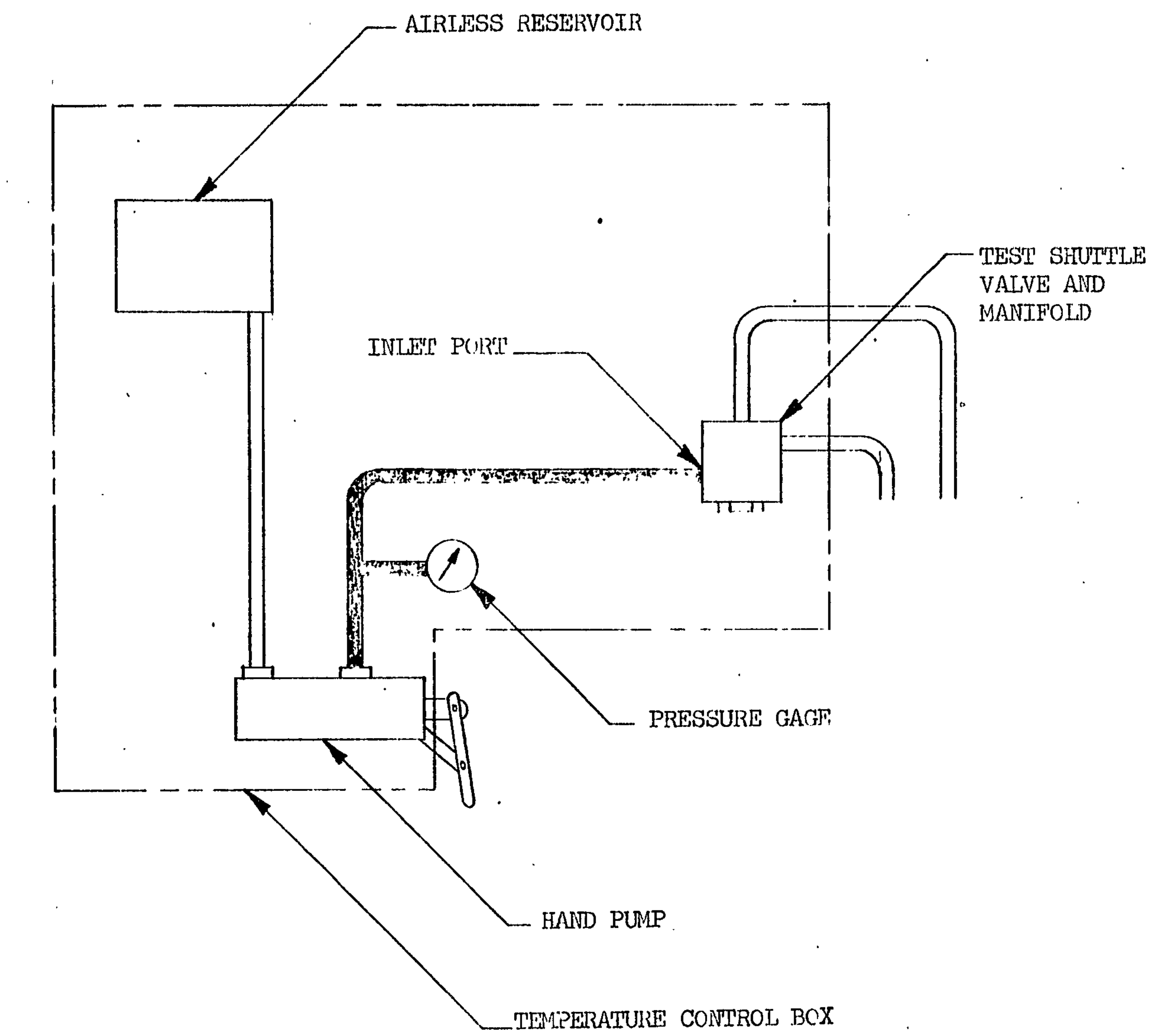


FIGURE 3

SETUP FOR EXTREME TEMPERATURE TEST

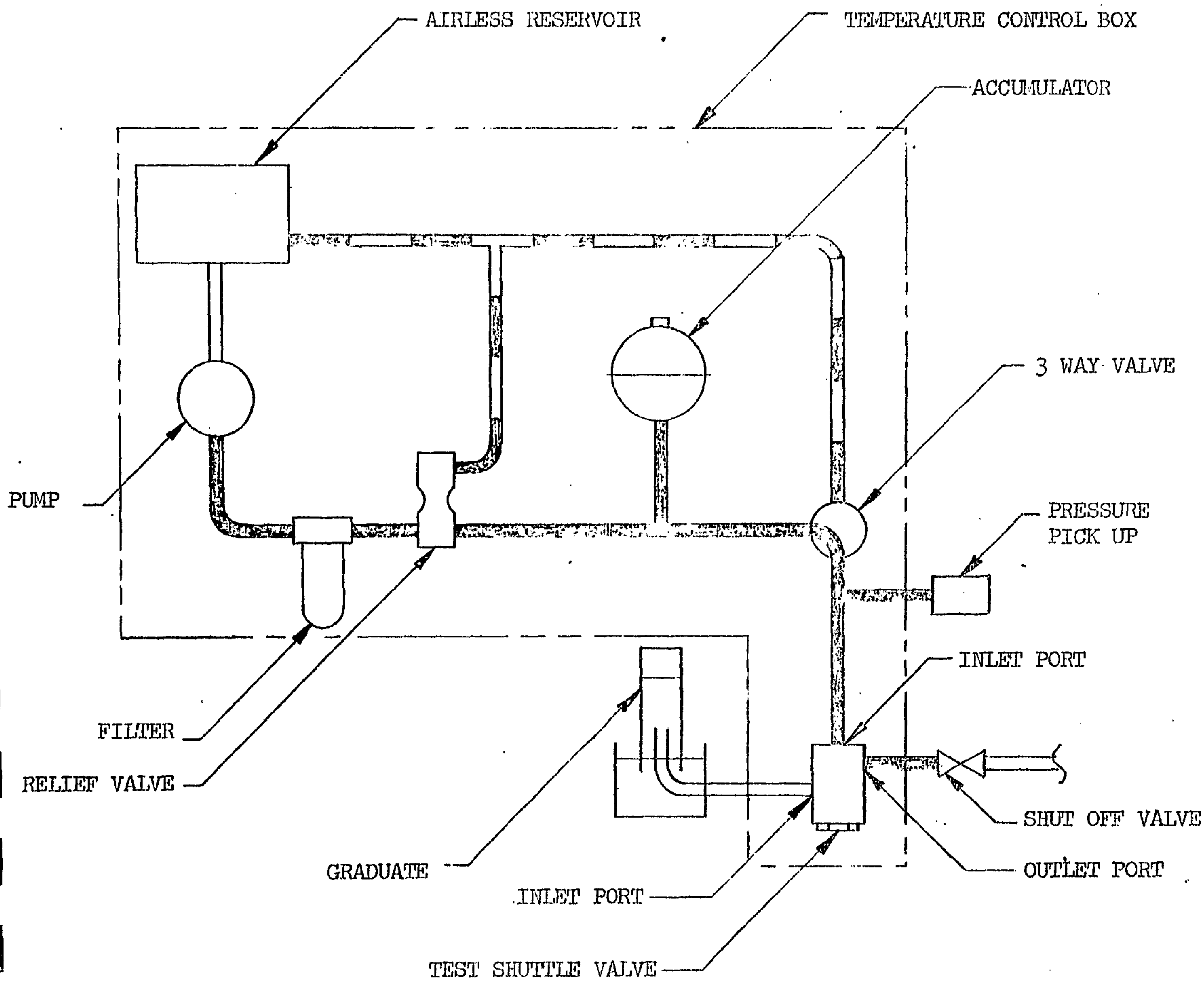


FIGURE 4

SET UP FOR IMPLUSE CYCLING TEST

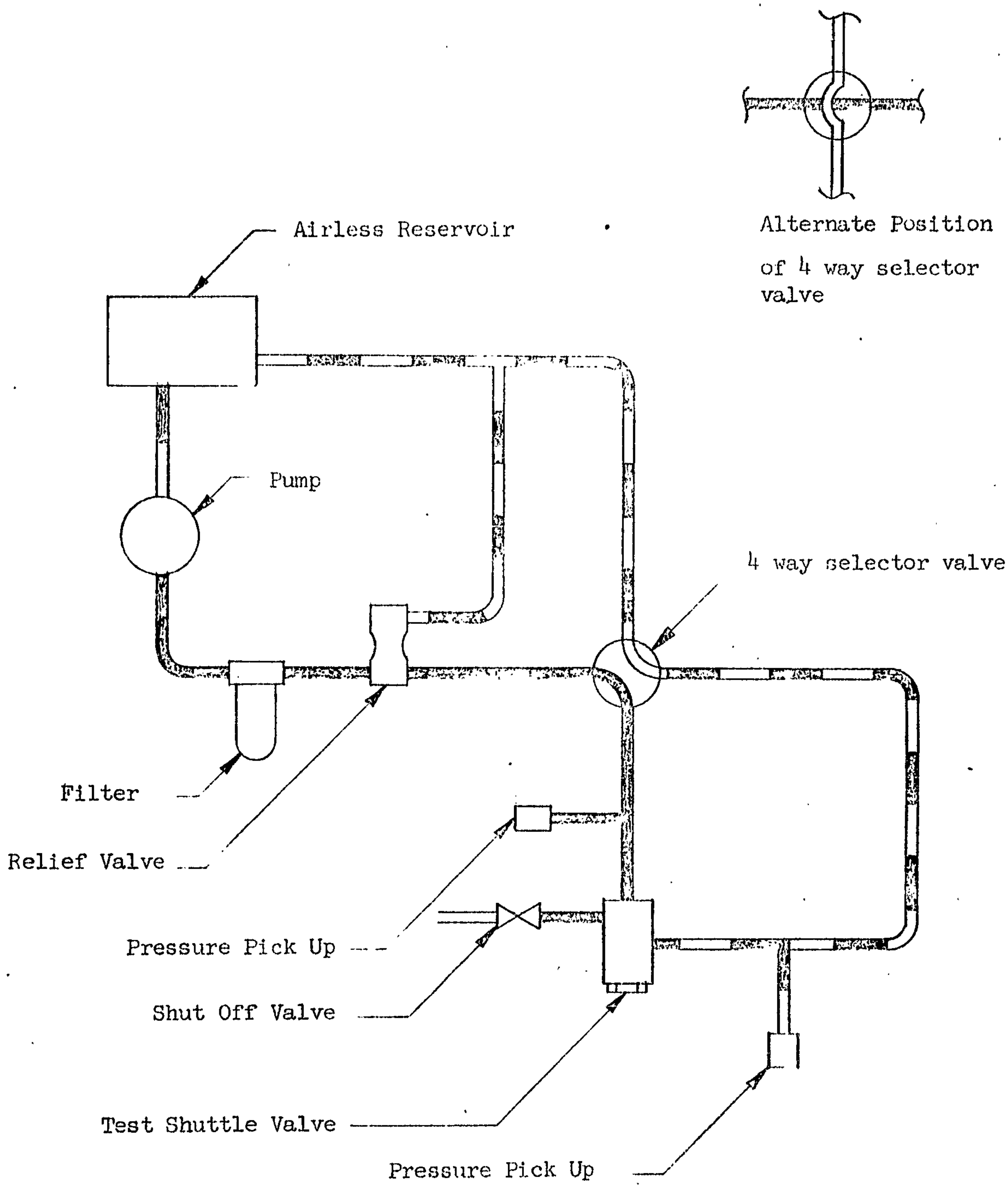


Figure 5

Set up for Endurance Cycling Test

NOTES:

1. Rate of temperature rise or decay may vary within the shaded areas shown.

2. Approximately six and one half hours of endurance cycling are to be run in one day.

3. The ambient temperature shall be maintained between 450-650°F during the time from the 2nd hour through 5 1/2 hours of the spectrum shown.

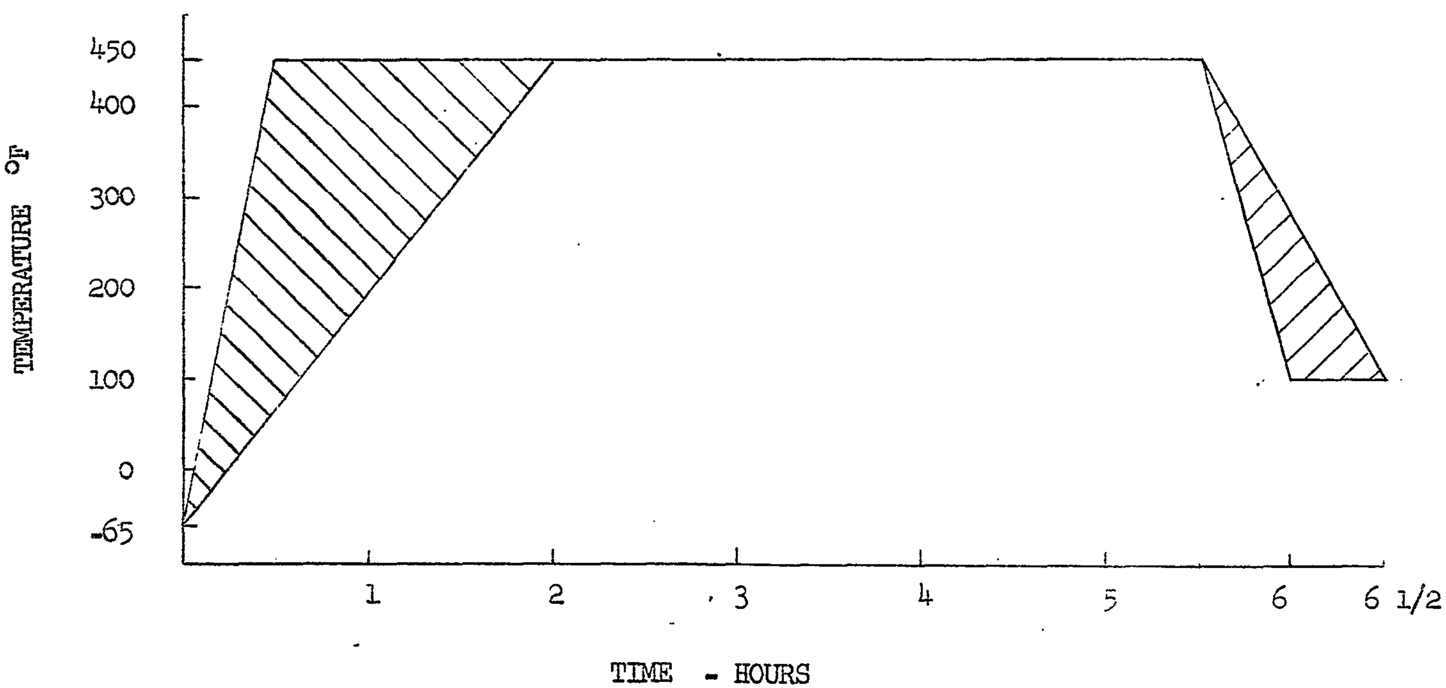


FIGURE 6

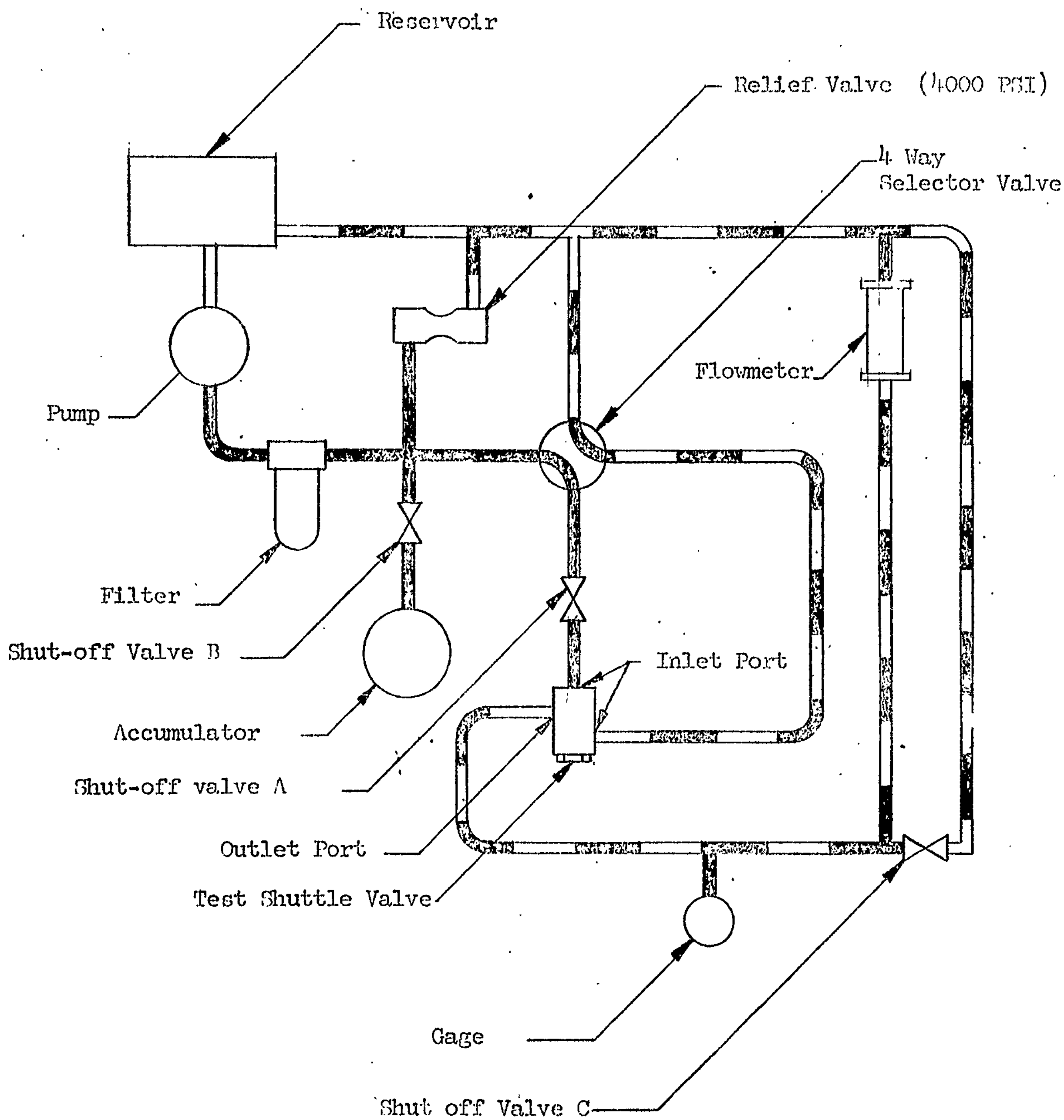


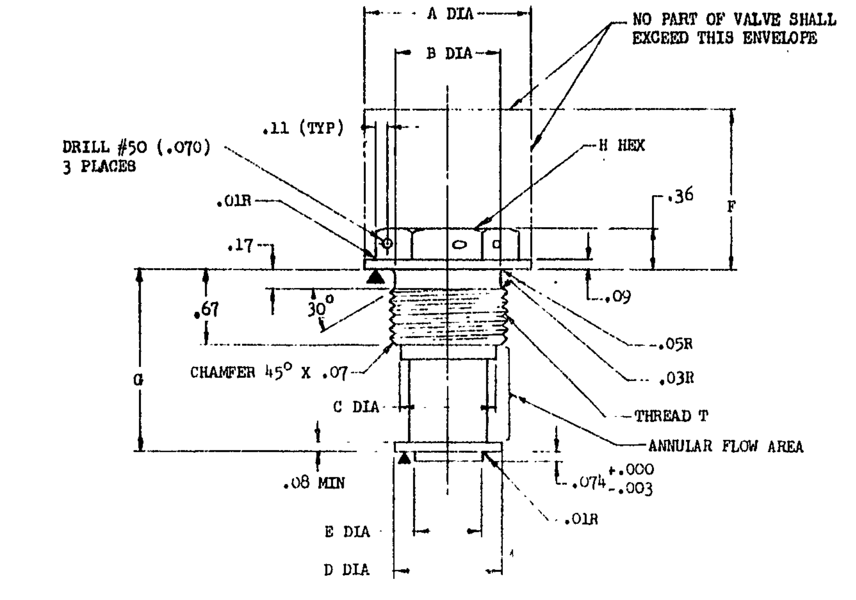
Figure 7

Setup for shuttling against a closed line and surge flow shuttling test

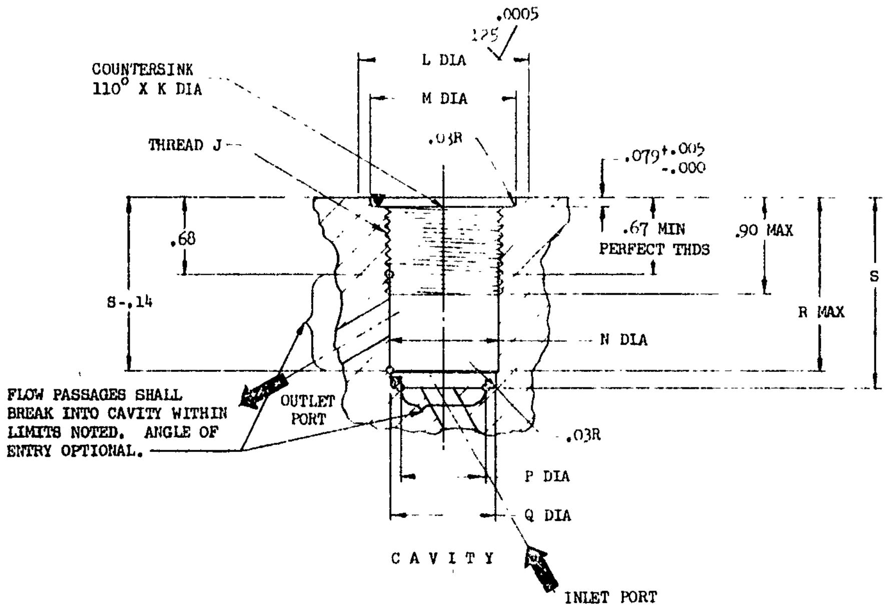
APPENDIX VI

Suggested MIL Specification for Pressure Relief Valve
Suggested MS Standard for Pressure Relief Valve

FED. SUP CLASS



V A L V E



C A V I T Y

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC PRESSURE RELIEF** 4,000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

VALVE DIMENSIONS

PART NUMBER	THREAD T	A DIA	B DIA +.000 -.005	C DIA MAX	D DIA +.000 -.002	E DIA +.000 -.001	F MAX	G +.000 -.003	H HEX MAX +.000 -.020	RATED FLOW G.P.M.	WEIGHT (MAX)-LBS.
MS -1	1 1/16-12UN-3A	1.52	.943	.950	.963	.594	1.42	1.610	1.312	4	.38
MS -2	1 5/16-12UN-3A	1.73	1.193	1.120	1.120	.750	1.32	1.820	1.500	25	.69

CAVITY DIMENSIONS

CAVITY FOR PART NUMBER	THREAD J	K DIA	L DIA MIN	M DIA +.002 -.000	N DIA +.0100 -.0000	P DIA MAX	Q DIA +.002 -.000	R MAX	S +.003 -.000
MS -1	1 1/16-12UN-3B	1.062	1.52	1.312	.9723	.783	.968	1.54	1.689
MS -2	1 5/16-12UN-3B	1.312	1.76	1.500	1.2223	.940	1.125	1.75	1.899

DETAIL REQUIREMENTS

TEMPERATURE LIMITS - +450°F FLUID AND +650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE - OPERATING 4000 PSI, PROOF ,000 PSI, BURST 10,000 PSI
FLUID - SPECIFICATION MIL-H-8446
SEALS - SPECIFICATION MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE
PRESSURE DROP - ADJUSTABLE FROM 3850 TO 4850 PSI AT RATED FLOW

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16/ RHR. ALL OTHER SURFACES 125/ RHR. .0005
REFERENCE SPECIFICATION MIL-STD-10.
TOLERANCES: THE SEALING SURFACE OF VALVE DIAMETERS "D" AND "A" SHALL BE PARALLEL WITHIN .002 FIR AND SHALL BE PERPENDICULAR TO THREAD "T" AXIS WITHIN .001 FIR. VALVE DIAMETERS "E", "D" AND "A" SHALL BE CONCENTRIC TO THREAD "T" WITHIN .002 FIR. THE SEALING SURFACE OF CAVITY DIAMETERS "M" AND "Q" SHALL BE PARALLEL TO SURFACE DIAMETER "L" WITHIN .002 FIR. DIAMETRAL SURFACE "L" SHALL BE PERPENDICULAR TO THREAD "J" AXIS WITHIN .001 FIR. CAVITY DIAMETERS "L", "M", "N" AND "Q" SHALL BE CONCENTRIC TO THREAD "J" AXIS WITHIN .002 FIR.
TOLERANCES UNLESS OTHERWISE NOTED: DETAIL ±.01; ANGULAR ±2°.
THIS VALVE INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- .
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE APPLICABLE COMPLETE MS PART NUMBER, THE WORDS "PRESSURE RELIEF", THE RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON THE HEX OR FLANGE (IF USED) SURFACES SUCH THAT MARKINGS ARE VISIBLE AFTER VALVE INSTALLATION.

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE VALVE, MODULAR HYDRAULIC PRESSURE RELIEF 4,000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION
VALVE; AIRCRAFT HYDRAULIC PRESSURE RELIEF

1. SCOPE

1.1 Scope.- This specification covers cartridge-type modular hydraulic pressure relief valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Pressure relief valves shall be of the following classes:

Class 1 - 0 to 4 gallons per minute capacity
Class 2 - 0 to 25 gallons per minute capacity

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified:

Specifications

Federal

PPP-T-60 Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121 Barrier Material, Greasproof, Flexible, Waterproofed
MIL-I-6866 Inspection, Penetrant Method of
MIL-I-6868 Inspection Process, Magnetic-Particle
MIL-H-6875 Heat Treatment of Steels (Aircraft Practice) Process for
MIL-S-7742 Screw Threads, Standard, Aeronautical
MIL-M-7911 Marking, Identification of Aeronautical Equipment, Assemblies and Parts
MIL-H-8446 Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891 Hydraulic Systems, Type III Design, Installation, Tests and Data Requirements, General Specification For
MIL-D-70327 Drawings, Engineering and Associated Lists

Standards

MIL-STD-10 Surface Roughness, Waviness and Lay
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-143 Specification and Standards, Use of
MS-33540 Safety Wiring - General Practices for
MS-20995 Wire-Lock

Drawing

MS- Valve, Pressure Relief, Modular, Envelope for

2.2 Other publications - Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in the order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are premitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification - The pressure relief valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and Processes - Materials and processes used in the manufacture of these valves shall conform to the following requirements and to applicable specifications as defined in Section 2:

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion resisting type or shall be adequately protected to resist corrosion which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency. Ferrous alloys shall have a chromium content of 12 per cent or shall be suitably protected against corrosion. In addition cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid.

3.2.2 Sub-zero stabilization of steel - Close-fitting, sliding steel parts shall be cold stabilized in accordance with specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic Parts - Plastic parts shall be used only with the approval of the procuring agency for each application.

3.3 Parts - Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the contractor's drawings.

3.4 Design and construction

3.4.1 Envelope - The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification, and MS________

3.4.2 Hydraulic fluid - The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range - The valves shall be designed to meet the functional and operational requirements of this specification throughout a range of -65°F to 450°F fluid temperature and -65°F to 650°F ambient temperature.

3.4.4 Threads - Only class 3 threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals - Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying - Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with Standard Drawings MS-33540 and MS-20995.

3.4.7 Retainer rings - Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valve.

3.4.8 Structural Strength - The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight - The weight shall be kept to a minimum consistent with good design, and shall be as specified on the applicable MS standard drawing.

3.4.10 Mounting position - The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control - The valves shall be designed to pass rated flow per 1.2 from inlet port to outlet. Flow shall be checked or blocked from outlet to inlet ports.

3.4.12 Surface roughness - Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.4.13 Filters - Pilot operated relief valves having an orifice which is less than 0.07 inches in diameter shall be protected by a filter element. The filter shall consist of a wire mesh screen in which the smallest hole dimension is not less than 0.008 inch and the largest hole dimension is not greater than 0.012 inch.

3.5 Interchangeability

3.5.1 Manufacturer's Parts - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability - Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification - Each valve shall have the identifying markings placed so that the identification can be read when the valve is installed in a manifold cavity. Each valve shall be permanently and legibly marked with the following information, per MIL-M-7911.

Valve, pressure relief
MS No.
Manufacturer's Part No.
Manufacturer's Name of Trademark

In addition, the pressure setting shall be stamped into a metal tag which is attached to the safety wire securing the adjustment or adjustment cover.

3.7 Workmanship

3.7.1 Quality - Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contaminant. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical Defect Inspection - All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated Flow and Operating Pressures - The valves shall be designed to operate in a hydraulic system having a rated pressure of either 3,000 psi or 4,000 psi. The valves shall be adjustable to provide rated flows at differential pressures from 3850 psi to 4850 psi.

3.8.2 Cracking Pressure

3.8.2.1 Flow - Cracking pressure shall be that differential pressure, during increasing pressure, which will produce a maximum flow of 6 cc per minute for class 1 valves and 9 cc per minute for class 2 valves, when tested per paragraph 4.6.3.

3.8.2.2 Minimum Pressure Setting - When the valves are set at a minimum pressure of 3850 psi, the cracking pressure shall not be less than 3311 psi (86 per cent of rated flow pressure), when tested per paragraph 4.6.3.1.

3.8.2.3 Maximum pressure setting.- When the valves are set at a maximum pressure of 4850 psi, the cracking pressure shall not be less than 4171 psi (86 per cent of rated flow pressure), when tested per paragraph 4.6.3.2.

3.8.3 Reseating Pressure

3.8.3.1 Flow- Reseating pressure shall be that differential pressure, during decreasing pressure, which will provide a maximum flow of 6 cc per minute for class 1 valves and 9 cc per minute for class 2 valves, when tested per paragraph 4.6.3.

3.8.3.2 Minimum pressure setting - When the valves are set at a minimum pressure of 3850 psi, the reseating pressure shall not be less than 3311 psi (86 per cent of rated flow pressure), when tested per paragraph 4.6.3.1.

3.8.3.3 Maximum pressure setting - When the valves are set at a maximum pressure of 4850 psi, the reseating pressure shall not be less than 4171 psi (86 per cent of rated flow pressure), when tested per paragraph 4.6.3.2.

3.8.4 Valve Leakage

3.8.4.1 The valves shall not show evidence of external leakage when 6,000 psi proof pressure is applied per paragraph 4.6.2.

3.8.4.2 When pressure is applied in the reverse direction to the valve per paragraph 4.6.4, class 1 valve leakage shall not exceed 6 cc per minute and class 2 valve leakage shall not exceed 9 cc per minute.

3.8.4.3 During the endurance test of the valve per paragraph 4.6.6, class 1 valve leakage shall not exceed 4 cc per minute and class 2 valve leakage shall not exceed 6 cc per minute.

3.8.4.4 During normal temperature performance per paragraph 4.6.3 and extreme temperature performance per paragraph 4.6.5, class 1 valve leakage shall not exceed 4 cc per minute and class 2 valve leakage shall not exceed 6 cc per minute.

3.8.5 Burst Pressure - When 10,000 psi is applied to the valve per paragraph 4.6.8, no rupture of internal or external parts shall be evident.

3.8.6 Proof Pressure - When 6,000 psi is applied to the valve per paragraph 4.6.2, there shall be no evidence of permanent set, failure or leakage.

3.8.7 Endurance - Valves shall be capable of 50,000 cycles when tested per paragraph 4.6.6.

3.8.8 Vibration.- The valves shall be capable of withstanding vibrations from 60 cps through 2000 cps at 15 "g's" and vibrations with an amplitude of 0.08 inch total excursion from 5 cps through 60 cps along the three mutually perpendicular axes, when tested per paragraph 4.6.7.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility - The manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the procuring agency. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests.- The inspection and testing of relief valves shall be classified as follows:

(a) Qualification tests
(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of relief valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F using the most adverse demensions. The room temperature reference point shall be 70°F.

4.3.2 Tests - The qualification tests shall consist of the following tests which shall be conducted in the order listed.

(a) Examination of product (per 4.6.1)
(b) Proof pressure (450°F) (per. 4.6.2.1)
(c) Normal temperature performance (minimum setting) (per 4.6.3.1.)
(d) Normal temperature performance (maximum setting)(Per 4.6.3.2.)
(e) Reverse flow checking (per 4.6.4.)
(f) Extreme temperature performance(per 4.6.5.)
(g) Endurance (per 4.6.6.)
(h) Vibration(per 4.6.7)
(i) Burst pressure (per 4.6.8)

4.4 Acceptance tests - Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the valves or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

(a) Examination of product (per 4.6.1.)
(b) Proof pressure (95 ± 15°F) (per 4.6.2.2.)
(c) Normal temperature performance (maximum setting)(per 4.6.3.2.)
(d) Reverse flow checking (per 4.6.4.)

4.5 Test conditions

4.5.1 Test fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95 ± 15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination.- Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer

or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of Particle	Percent by Weight of Total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	18 ± 3
over 40 micron	9 ± 3

4.5.4 Filtrations.- The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing - All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity and which is acceptable to the procuring agency.

4.5.5.2 Acceptance Test Housing.- The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test Methods

4.6.1 Examination of Product.- Each valve shall be carefully examined to determine conformance with the requirements of this specification for workmanship, marking, conformance to applicable drawings, or for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Proof pressure test

4.6.2.1 Proof pressure test for qualification.- The fluid temperature shall be 450 ± 15°F for this test. After bleeding all air from the valve and plugging the outlet port, a proof pressure of 6,000 psi shall be applied. The proof pressure shall be held for at least two minutes. This test shall be repeated with the pressure port plugged and pressure applied to the outlet port. There shall be no evidence of external leakage, permanent set, or failure.

4.6.2.2 Proof pressure test for acceptance.- The fluid temperature shall be 95 ± 15°F for this test. After bleeding all air from the valve and plugging the outlet port, a proof pressure of 6,000 psi shall be applied. The proof pressure shall be held for at least two minutes. This test shall be repeated with the pressure port plugged and pressure applied to the outlet port. There shall be no evidence of external leakage, permanent set, or failure.

4.6.3 Normal temperature performance

4.6.3.1 Normal temperature performance at minimum setting.- The fluid temperature shall be 95 ± 15°F for this test. Leakage shall be measured at the outlet port during the minute following a two minute waiting period. The test valve shall be installed in a set up similar to schematic Figure 1. The valve shall be adjusted to deliver rated flow of 4 and 25 gpm for class 1 and 2 valves, respectively, at a differential pressure of 3850 psi. The differential pressure shall then be reduced until reseat pressure is determined. Reseat pressure is defined as the differential pressure, upon decreasing pressure, which will produce a maximum flow 6 and 9 cc/min in the class 1 and 2

valves, respectively. Differential pressure shall be reduced slowly to 2880, 1930, and 962 psi and leakage rates measured at each of these values. Differential pressure shall then be increased to 962, 1930, and 2880, psi and leakage rate measured at each of these values. The pressure shall be further increased until a flow of 6 and 9 cc/minute for the class 1 and 2 valves, respectively, is obtained. The pressure at this leakage rate shall be recorded as the cracking pressure. Neither the cracking pressure nor the reseat pressure shall be less than 3311 psi (86% of rated flow pressure). Leakage rates shall not exceed the following values of Table I.

TABLE I - ALLOWABLE LEAKAGE AT MINIMUM SETTINGS

	CLASS 1 VALVE	CLASS 2 VALVE
Pressure, psi	Max. Allowable Leakage	Max. Allowable Leakage
2880	4 cc/min.	6cc/min.
1930	4 cc/min.	6cc/min.
962	4 cc/min.	6cc/min.

4.6.3.2 Normal temperature performance at maximum setting - The fluid temperature shall be 95 ± 15°F for this test. Leakage shall be measured at the outlet port during the minute following a two minute waiting period. The test valve shall be installed in a set-up similar to schematic Figure 1. The valve shall be adjusted to deliver rated flow of 4 and 25 gpm for Class 1 and 2 valves, respectively, at a differential pressure of 4,850 psi. The differential pressure shall then be reduced until reseat pressure is determined. Reseat pressure is defined as the differential pressure, upon decreasing pressure, which will produce a maximum flow of 6 and 9 cc/min. in the class 1 and 2 valves, respectively. Differential pressure shall be reduced slowly to 3630, 2425 and 1210 and the leakage rate measured at each

pressure. Pressure shall then be increased and leakage measured at 1210, 2425, and 3630 psi. The pressure shall be further increased until a flow of 6 and 9 cc/minute for the class 1 and 2 valves, respectively, is obtained. The pressure at this leakage rate shall be recorded as the cracking pressure. Neither the cracking pressure nor the reseat pressure shall be less than 4171 psi (86% of rated flow pressure). Leakage rates shall not exceed the following values of Table II.

TABLE II
ALLOWABLE LEAKAGE AT MAXIMUM SETTINGS

	CLASS 1 VALVE	CLASS 2 VALVE
Pressure, psi	Max. Allowable Leakage	Max. Allowable Leakage
3630	4cc/min.	6cc/min.
2425	4cc/min.	6cc/min.
1210	4cc/min.	6cc/min.

4.6.4 Reverse flow checking - The fluid temperature shall be 95 ± 15°F for this test. Pressure of 6,000 psi shall be applied to the valve outlet port with the inlet or pressure port open. Leakage shall be measured during the third minute of a three minute waiting period. This test shall be repeated with 50 psi applied to the outlet port. Leakage during the third minute of a three minute waiting period shall not exceed 6 cc/min. and 9 cc/min. for the class 1 and class 2 valves, respectively.

4.6.5 Extreme temperature performance

4.6.5.1 Low temperature performance - The test set up shall be maintained at -65°F or colder for at least 8 hours prior to start of the test. The test shall be conducted with the valve adjusted to the maximum pressure setting. The valve shall be installed in a set up similar to schematic

Figure 2. Fluid shall be pumped through the relief valve and the differential pressure reduced until the valve reseats. The reseat pressure shall be recorded. The test shall be repeated with the fluid warmed up to -20°F. The reseat pressure shall not be less than 4,171 psi.

4.6.5.2 High temperature performance - The valve shall be adjusted to the maximum setting for this test. The test set up shall be stabilized at a temperature of 450 ± 15°F for at least 4 hours before the test is started. The valve shall be installed in a set-up similar to schematic Figure 2. Fluid shall be pumped through the valve at rated flow, and the differential pressure shall be decreased slowly until the valve reseats. The reseat pressure shall be recorded. The differential pressure shall be further reduced to 3630, 2425, and 1210 psi and the leakage rate measured at each of these pressures. After further reducing pressure, the pressure shall be increased to 1210, 2425 and 3630 psi and the leakage rate measured at each differential pressure. The reseat pressure shall not be less than 4,171 psi. The leakage rate shall not exceed 4 cc/min. and 6 cc/min. for the class 1 and class 2 valves, respectively, during the decreasing pressure and increasing pressure leakage checks.

4.6.6 Endurance - The endurance test shall be performed with the valve adjusted to the maximum pressure setting for rated flow at room temperature. The temperature of the test set up shall follow a series of seven repetitions of the time - temperature spectrum per Figure 3. Each spectrum should take approximately six and one half hours to complete. The first, fourth, and seventh spectrum shall begin at -65°F after the set up has soaked at -65°F for 8 hours. The spectrum shall begin at 95 ± 15°F on the second, third,

fifth, and sixth repetitions. The rate of temperature rise and decay shall be within the shaded areas shown. After completion of all endurance cycling the fluid shall be stabilized at 95 ± 15°F for leakage tests. The valve shall be installed in a set-up similar to schematic Figure 2. The valve shall be cycled by imposing rated flow and then reducing differential pressure to 500 psi or less for a total of 50,000 cycles. Cycling shall be performed at a rate of 17 - 20 cpm. Upon completion of the 50,000 endurance cycles, leakage tests shall be performed as follows: Inlet pressure shall be gradually decreased until leakage rates of 9cc/min. and 12cc/min. can be determined for the class 1 and class 2 valves, respectively. Differential pressure shall be further reduced and leakage measurements made at 3630, 2425, and 1210 psi. The results of this test shall not exceed the following values of Table III.

TABLE III

ENDURANCE TEST ACCEPTANCE VALUES

Controlled Variable	Class 1 Valve	Class 2 Valve	Minimum Differential Pressure	Maximum Allowable Leakage Rate
Flow Rate	9cc/min.		4,171	
		12cc/min.	4,171	
Differential Press.	3630 psi			4 cc/min.
	2425 psi			4 cc/min.
	1210 psi			4 cc/min.
		3630 psi		6 cc/min.
		2425 psi		6 cc/min.
		1210 psi		6 cc/min.

4.6.7 Vibration test.- When friction-type adjustment screws are utilized in the valve design, these adjustment screws shall be moved through the full adjustment range 15 times prior to starting the vibration test. The valve shall be set at the maximum setting for these test. The fluid temperature shall be 95 ± 15°F. The valve shall be cycled at a rate of 17 - 20 cpm by imposing rated flow through the valve and then reducing the differential pressure to zero. While the valve is being cycled in this manner, it shall be vibrated as outlined in Table IV.

TABLE IV

SEQUENCE OF VIBRATION TESTING

FIRST AXES (Horizontal)	Step 1 Survey for resonance, 5-2,000 cps in 30 minutes. Amplitude 0.08 Step 2 - As Step 1 in total excursion for frequency from Step 3 - As Step 1 5 to 60 cps: vibrate at 15 "g's" from 60-2,000 cps. Step 4 Vibrate at most resonant frequency found in (1),(2) and (3) for 90 minutes. (If no resonance found, vibrate at 500 cps for 90 minutes) 4A After 23 minutes, change frequency to resonant +10%, determine reseat pressure. 4B After 23 minutes, change frequency to resonant -10%, determine reseat pressure. 4C Continue vibration at resonant frequency. 4D After 46 minutes, repeat 4A. 4E After 46 minutes, repeat 4B. 4F Continue vibration at resonant frequency. 4G After 69 minutes, repeat 4A. 4H After 69 minutes, repeat 4B. 4I Continue vibration at resonant frequency. 4J After 90 minutes, repeat 4A. 4K After 90 minutes, repeat 4B.
SECOND AXIS (90° to first)	Repeat Steps 1 thru 4 and 4A thru 4K above.
THIRD AXIS (90° to first and second)	Repeat Steps 1 thru 4 and 4A thru 4K above.

Reseat pressure as determined in steps 4A, 4B, 4D, 4E, 4G, 4H, 4J, and 4K in the procedure above shall not be less than 4,171 psi. There shall be no mechanical failure of parts resulting from this test.

4.6.8 Burst Pressure Test - The fluid temperature shall be $95 \pm 15^{\circ}F$ for this test. With the outlet port plugged, pressure shall be applied to the inlet port until 10,000 psi is reached. This pressure shall be held for 2 minutes. This test shall be repeated with the inlet port plugged and burst pressure applied to the outlet port. There shall be no rupture of external or internal parts.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging - Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A greaseproof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of Shipments - Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document
Name of part
MS part No.
Month and year of manufacture
Class or size

6. NOTFS

6.1 Intended Use - The pressure relief valves covered by this specification are intended for use in either 3,000 or 4,000 psi aircraft and missile hydraulic systems covered by Specification MIL-H-8891, and operating with hydraulic fluid conforming to Specification MIL-H-8446. The pressure relief valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering data.- Procurement documents should specify the following:

(a) Title, number and date of this specification.
(b) MS part number.
(c) Class
(d) Federal stock number.

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C.; however, information pertaining to qualification of products may be obtained for the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

Preparing Activity:

Navy - Bureau of Naval Weapons

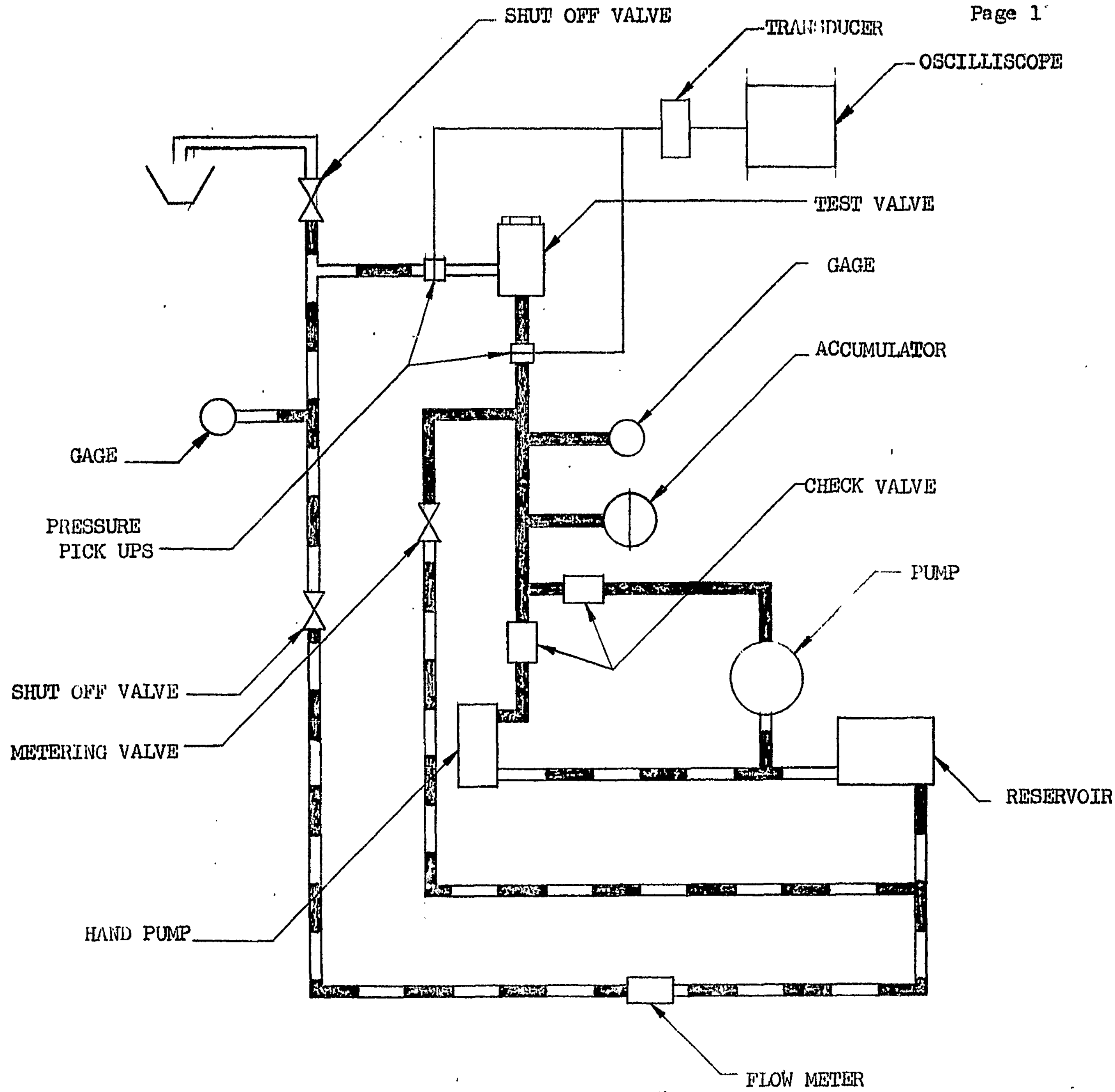


Figure 1

Diagram for Normal Temperature Performance Tests

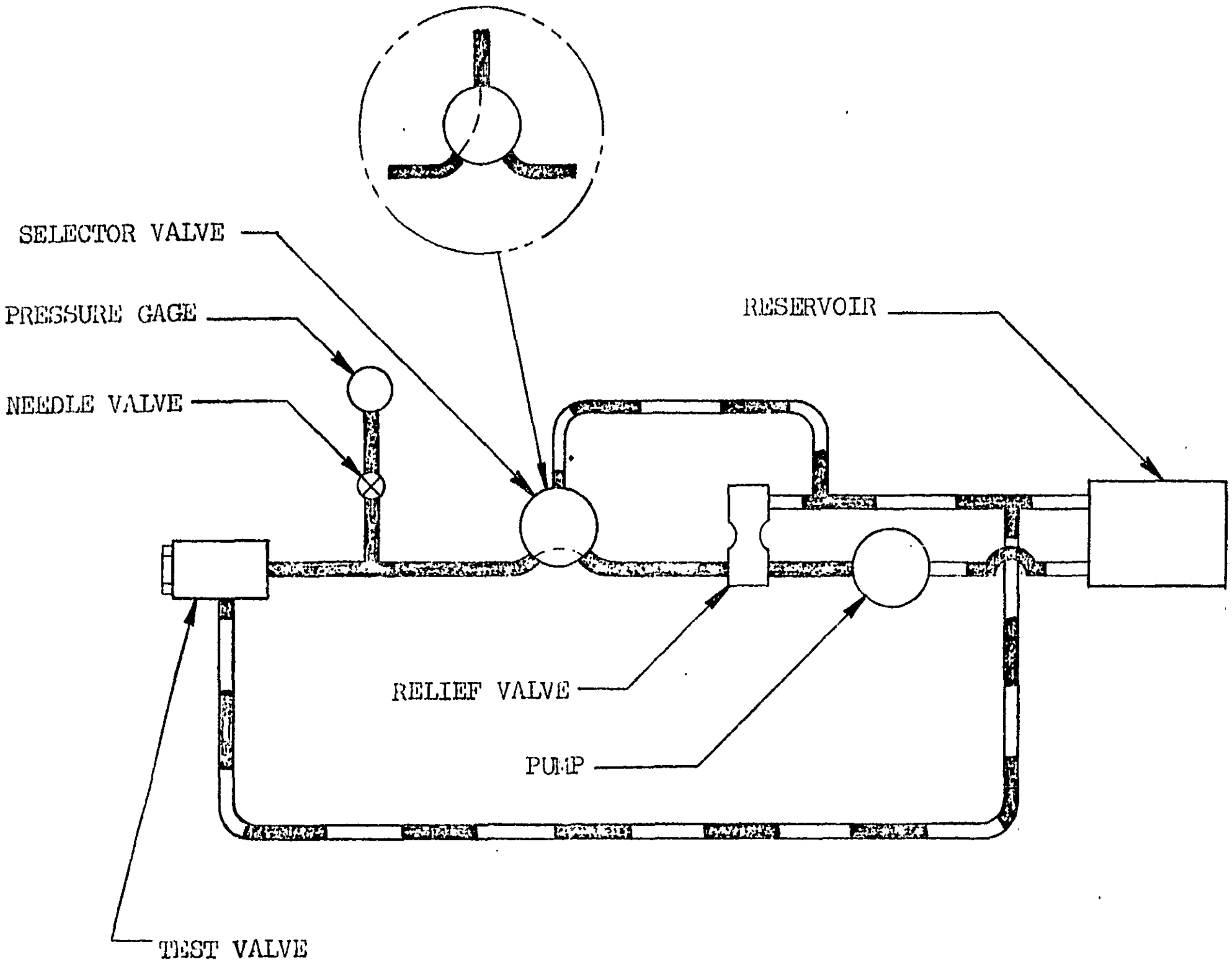


FIGURE 2

TYPICAL ENDURANCE TEST SET UP

NOTES:

1. Rate of temperature rise or decay may vary within the shaded areas shown.

2. Six and one half hours of endurance cycling are to be run in one day. Components are to be soaked overnight at the low temperature required to start the following day of testing.

3. The first, middle and last repetitions of this spectrum begin with fluid temperature of -65°F. All other runs shall begin with the fluid temperature at ambient (70° to 100°F).

4. The ambient temperature shall be maintained between 450 - 650°F during the time from the 2nd hour through 5-1/2 hours of the spectrum shown.

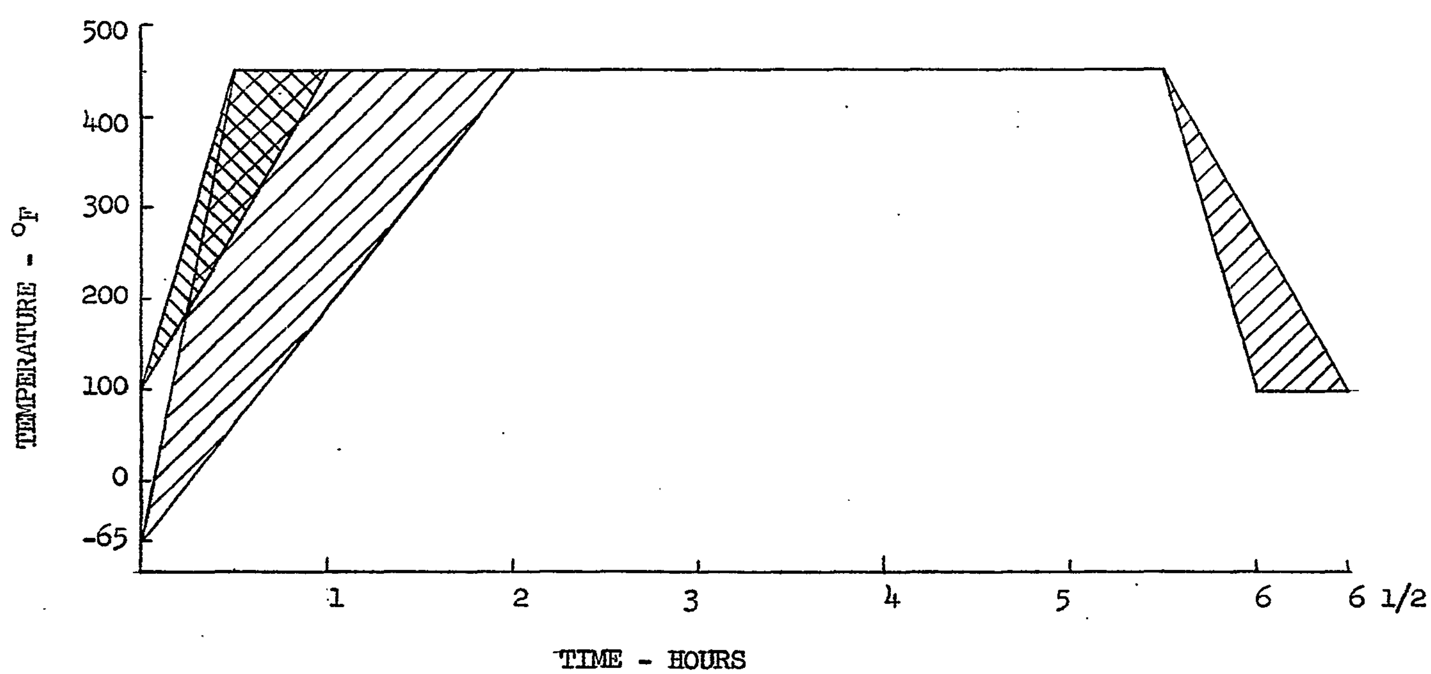


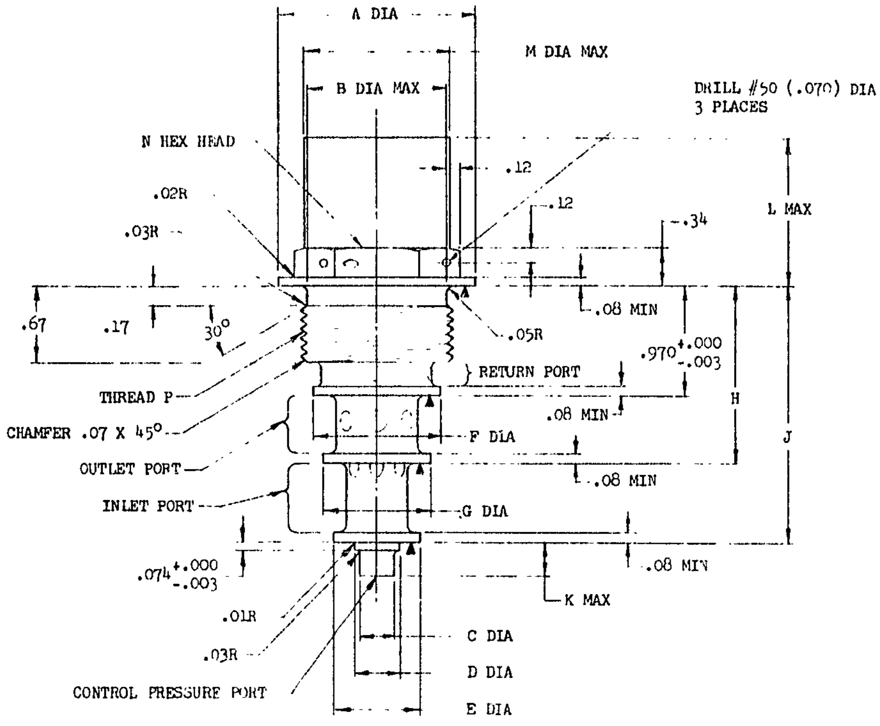
Figure 3
Time - Temperature Spectrum

APPENDIX VII

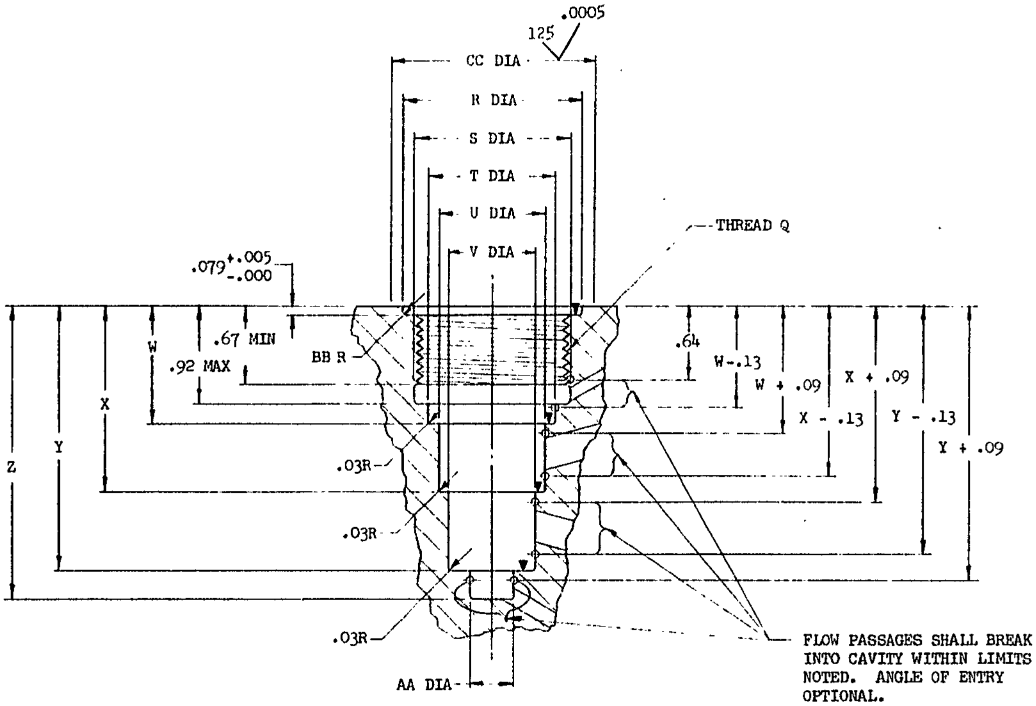
Suggested MIL Specification for Pressure Operated Shut-Off Valve

Suggested MS Standard For Pressure Operated Shut-Off Valve

FED. SUP CLASS



VALVE



CAVITY

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, PRESSURE OPERATED SHUT-OFF** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

DD FORM 1 SEP 57 672-1 *(Limited coordi ation)* PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

AER 55720T

FED. SUP CLASS

VALVE DIMENSIONS

PART NUMBER	FLOW RANGE GPM	THREAD P PER MIL-S-7742	A DIA	B DIA +.005 -.000	C DIA MAX	D DIA +.000 -.001	E DIA +.000 -.002	F DIA +.000 -.002	G DIA +.000 -.002	H +.000 -.003	J +.000 -.003	K MAX	L MAX	M DIA MAX	N HEX HEAD
MS -1	0-4	1 3/8-12UNF-3A	1.78	1.298	.31	.406	.776	1.151	.263	1.580	2.280	.30	1.50	1.31	1 5/16
MS -2	0-12	1 9/16-18NEF-3A	1.96	1.483	.47	[illegible]	[illegible]	[illegible]	1.120	1.740	2.700	.24	1.90	1.31	1 5/16
MS -3	0-25	2-12 UN-3A	2.46	1.869	.60	[illegible]	[illegible]	[illegible]	[illegible]	1.939	3.080	.24	2.30	1.68	1 11/16

CAVITY DIMENSIONS

CAVITY FOR PART NUMBER	FLOW RANGE GPM	THREAD Q PER MIL-S-7742	R DIA +.002 -.000	S DIA +.005 -.000	T DIA +.002 -.000	U DIA +.002 -.000	V DIA +.002 -.000	W +.003 -.000	X +.003 -.000	Y +.003 -.000	Z MIN	AA DIA MIN	AA DIA MAX	BB RADIUS	CC DIA
MS -1	0-4	1 3/8-12UNF-3B	1.625	1.398	1.156	.968	.781	1.049	1.659	2.359	2.61	.37	.39	.03	1.84
MS -2	0-12	1 9/16-18NEF-3B	1.812	1.572	1.312	1.125	.937	1.049	1.819	2.772	2.97	.49	.55	.03	2.05
MS -3	0-25	2-12 UN-3B	2.312	[illegible]	1.687	1.500	1.281	1.049	2.009	3.139	3.33	.68	.88	.03	3.55

DETAIL REQUIREMENTS

TEMPERATURE LIMITS - +450°F FLUID AND +650°F AMBIENT MAXIMUM . VALVE SHALL FUNCTION AT -65°F.
PRESSURE - OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI
FLUID - SPECIFICATION MIL-H-8446
SEALS - SPECIFICATION MIL-
LIFE SEE SPECIFICATION MIL- FOR ENDURANCE
PRESSURE DROP 25 PSI MAXIMUM AT RATED FLOW

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16√ RHR. ALL OTHER SURFACES 125√ RHR. REFERENCE SPECIFICATION MIL-STD-10.
TOLERANCES: THE SEALING SURFACES OF VALVE DIAMETERS "F", "G" AND "E" SHALL BE PARALLEL TO SEALING SURFACES OF VALVE DIAMETER "A" WITHIN .002 FIR. THE SEALING SURFACE OF VALVE DIAMETER "A" SHALL BE PERPENDICULAR TO THREAD "P" (AXIS) WITHIN .001 FIR. VALVE DIAMETERS "A", "F", "G" AND "E" SHALL BE CONCENTRIC TO THREAD "P" (AXIS) WITHIN .002 FIR. CAVITY DEPTHS $.079^{+.005}_{-.000}$, "W", "X" AND "Y" SHALL BE PARALLEL TO SURFACES "CC" WITHIN .002 FIR.
DIAMETRAL SURFACE "CC" SHALL BE PERPENDICULAR TO THREAD "Q" (AXIS) WITHIN .001 FIR. CAVITY DIAMETERS "CC", "R", "T", "U", AND "V" SHALL BE CONCENTRIC TO THREAD "Q" (AXIS) WITHIN .002 FIR.
TOLERANCES UNLESS OTHERWISE NOTED: DETAIL ±.010; ANGULAR ±2°.
THIS VALVE INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- .
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE APPLICABLE COMPLETE MS PART NUMBER, THE WORDS "PRESS. OPER. SHUT-OFF", THE RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON THE HEX OR FLANGE SURFACES SUCH THAT MARKINGS ARE VISIBLE WHEN THE VALVE IS INSTALLED.

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, PRESSURE OPERATED SHUT-OFF** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION
VALVES: AIRCRAFT HYDRAULIC PRESSURE OPERATED SHUT-OFF

1. SCOPE

1.1 Scope.- This specification covers cartridge-type modular hydraulic pressure operated shut-off valves for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Shut-off valves shall be of the following classes:

Class 1 - 0 to 4 gallons per minute capacity

Class 2 - 0 to 12 gallons per minute capacity

Class 3 - 0 to 25 gallons per minute capacity

1.3 Size.- Pressure operated shut-off valve shall be furnished in sizes indicated on MS   Drawing.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproofed; Flexible Waterproofed
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection Process, Magnetic Particle
MIL-H-6875	Heat Treatment of Steels (Aircraft Practice) Process for
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-M-7911	Marking, Identification of Aeronautical Equipment, Assemblies and Parts
MIL-H-8446	Hydraulic Fluid, Non-petroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III, Design, Installation, Tests and Data Requirements, Aircraft, General Specification For
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Specifications and Standards, Use of

MS-33540	Safety Wiring, General Practices For
MS-20995	Wire-Lock

Drawings

MS-	Shuttle Valve, Modular, Envelope For

2.2 Other Publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in the order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are premitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification.- The shut-off valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and Processes.- Materials and processes used in the manufacture of these valves shall conform to the following requirements and to applicable specifications as defined in Section 2:

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion, during normal service life of the valve assemblies, which may result from such conditions as dissimilar metal combinations, moisture, salt spray and high temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring activity. Ferrous alloys shall have a chromium content of not less than 12 per cent or shall be suitably

protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero Stabilization of Steel.- Close-fitting, sliding steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic Parts.- Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts.- Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the contractor's drawings.

3.4 Design and Construction.

3.4.1 Envelope.- The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification, MS__________ and applicable drawings.

3.4.2 Hydraulic Fluid.- The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature Range.- The valves shall be designed to meet the functional and operational requirements of this specification throughout a range of -65°F to 450°F fluid temperature and -65°F to 650°F ambient temperature.

3.4.4 Threads.- Only class 3 straight threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals.- Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with Standard Drawings MS-33540 and MS-20995.

3.4.7 Retainer Rings.- Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valve.

3.4.8 Structural Strength.- The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight - The weight shall be kept to a minimum consistent with good design, and shall be as specified on the applicable drawing.

3.4.10 Mounting Position.- The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow

3.4.11.1 Rated Flow.- The valves shall be designed to pass rated flow per 1.2, and shall be capable of passing 150 percent of rated flow without damage to the valve.

3.4.11.2 Flow Control - Valve position shall be controlled by hydraulic pressure applied at the control pressure port. (Refer to Figure 1). The valves shall be designed to pass rated flow from inlet port to outlet port with the valve in the open position. The valve shall block flow from inlet to outlet with the valve in the shut-off position. The valve shall be spring loaded to the shut-off position in case of control pressure failure. A return pressure cavity shall be included so that leakage past internal slider can be directed back to return rather than overboard.

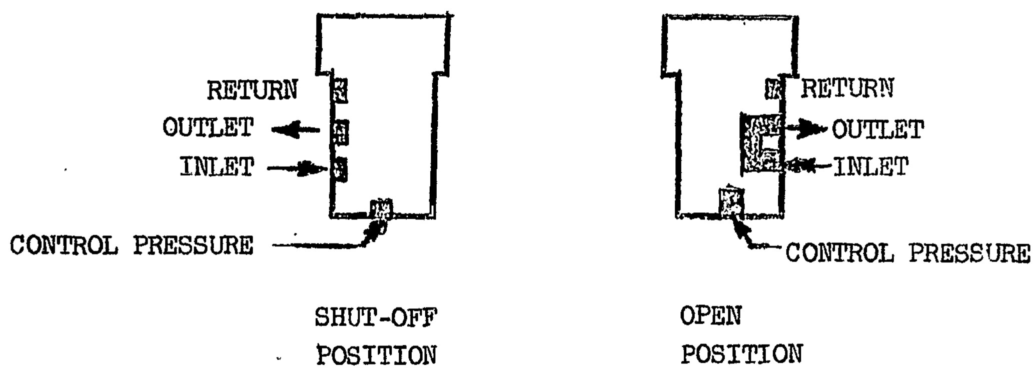


FIGURE 1

SCHEMATIC OF FLOW CONTROL

3.4.12 Surface Roughness - Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's Parts - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's

part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification.- Each valve shall have the identifying markings placed on the hex head or the flange so that the identification can be read when the valve is installed in a manifold cavity. Each valve shall be permanently and legibly marked with the following information, per MIL-M-7911.

Valve, Shut-off

MS No.

Manufacturer's Part No.

Manufacturer's Name or Trademark

In addition, the pressure setting shall be stamped into a metal tag which is attached to the safety wire securing the adjustment or adjustment cover.

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contaminant. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical Defect Inspection.- All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated Pressure.- The valves shall be designed to operate satisfactorily in a hydraulic system, having a rated pressure 4,000 psi, when tested per 4.6.4.

3.8.2 Operating Pressure.- The valves shall be designed to insure satisfactory operation and service life throughout the operating range of 0 to 4,000 psi, when tested per 4.6.4. The valves shall be capable of operation at 6,000 psi.

3.8.3 Proof Pressure.- The valves shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.2 and there shall be no evidence of external leakage, permanent set, or other damage.

3.8.4 Burst Pressure.- The valves shall be designed so as not to burst at any pressure below 10,000 psi, when tested per 4.6.8.

3.8.5 Net Pressure Drop and Full Open Position.

3.8.5.1 Full Open Position.- The full open position of the valves shall be defined as that condition during increasing pressure at which the rated flow from inlet port to outlet port produces a net pressure drop across the valve of 25 psi, when tested per 4.6.4. The pressure at the inlet port shall be 4,000 psi.

3.8.5.2 Net Pressure Drop.- The net pressure drop of the valves shall be the difference in pressure drop across the housing with the valve installed and the pressure drop across the housing with the valve removed and the correspondi cavity plugged, when tested per 4.6.4. Net pressure drop shall not exceed 25 psi at rated flow and room temperature, when tested per 4.6.4. There shall be no evidence of external leakage.

3.8.6 Leakage and Shut-Off Position

3.8.6.1 Shut-Off Position.- Shut-off position of the valves shall be defined as that condition during decreasing pressure at which the leakage from inlet port to outlet port does not exceed or is less than the values of Table I, when tested per 4.6.4. The pressure at the inlet port shall be 4,000 psi.

3.8.6.2 Leakage.- With pressures applied to ports individually and in combination, the combined leakage from the unpressurized ports shall not exceed the values noted in Table I, when tested per 4.6.3.

TABLE I

MAXIMUM ALLOWABLE COMBINED LEAKAGE

VALVE CLASS	COMBINED LEAKAGE
1	8cc/min.
2	10cc/min.
3	12cc/min.

3.8.7 Control Pressure.- The valves shall be designed so that the pressure settings can be adjusted within the limits noted in Table II. The difference of pressure between full open and shut-off shall not exceed 350 psi, when tested per 4.6.4.

TABLE II

PRESSURE SETTING	RETURN PRESSURE	FULL OPEN PRESSURE	SHUT-OFF PRESSURE
1	400 psi	1600 psi MAX	1250 psi MIN
	50 psi	1250 psi MAX	900 psi MIN
2	400 psi	2000 psi MAX	1650 psi MIN
	50 psi	1650 psi MAX	1300 psi MIN

3.8.8 Extreme Temperature Performance.

3.8.8.1 Low Temperature.- The valves shall operate satisfactorily within the limits of Tables I and II, except that the net pressure drop at rated flow shall not exceed 100 psi at -65°F and 80 psi at -20°F, when tested per 4.6.5.1.

3.8.8.2 Rapid Warm-Up.- The valves shall operate satisfactorily within the limits of Tables I and II during rapid warm-up, when tested per 4.6.5.2.

3.8.8.3 High Temperature.- The valves shall operate satisfactorily within the limits of Tables I and II, when tested per 4.6.5.3.

3.8.9 Endurance Cycling.- The valves shall meet the leakage requirements of Table I, increased by fifty percent, after 20,000 cycles of operation, at 14 cpm, when tested per 4.6.6. During cycling there shall be no evidence of seizing or binding of mating parts.

3.8.10 Vibration.- The valves shall be capable of withstanding vibrations from 5 to 2,000 cps with an amplitude of 0.04 inch (0.08 inch total excursion) or "15 g's", whichever is limiting, along three mutually perpendicular axes, when tested per 4.6.7, except that allowed internal leakage may be increased 50 percent.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection Responsibility.- Unless otherwise specified herein, the manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of Tests.- The inspection and testing of the valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification Tests.

4.3.1 Sampling Instructions.

4.3.1.1 Samples of pressure operated shut-off valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Qualification Tests.- The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification. Unless otherwise noted, the valve shall be adjusted to pressure setting number 1 noted in Table II.

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2.

(c) Leakage per 4.6.3.

(d) Functioning per 4.6.4.

(e) Extreme temperature performance per 4.6.5.

(f) Endurance per 4.6.6.

(g) Vibration per 4.6.7.

(h) Burst pressure per 4.6.8.

4.4 Acceptance Tests.- Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each check valve shall be subjected to the following tests:

(a) Examination of product per 4.6.1.

(b) Proof pressure per 4.6.2.

(c) Leakage per 4.6.3.

(d) Functioning per 4.6.4.

4.5 Test Conditions.

4.5.1 Test Fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid Temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination.- Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of Particle	Percent by Weight of Total
0 to 5 micron	39±2
5 to 10 micron	18±3
10 to 20 micron	16±3
20 to 40 micron	18±3
over 40 micron	9±3

4.5.4 Filtration.- The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test Housing

4.5.5.1 Qualification test Housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow cavity. The test housing must be acceptable to the procuring agency.

4.5.5.2 Acceptance Test Housing.- The tests in 4.4. may be conducted in the qualification test housing or in a housing having any other external configuration.

4.5.6 Net Pressure and Tare Pressure Readings.- The net pressure drop shall be determined by subtracting the tare pressure readings from the pressure drop readings obtained with the valve in the test housing. Tare pressure shall be determined by removing the valve from the test housing and plugging all openings except the inlet and outlet ports. Tare pressure readings shall be determined at rated flows with fluid stabilized at temperatures required by section 4.6 of this specification.

4.6 Test Methods.

4.6.1 Examination of Product.- Each valve shall be carefully examined to determine conformance with the requirements of this specification for workmanship, marking, conformance to applicable drawings, or for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or other equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Proof Pressure.- Proof pressure of 6000 psi shall be applied to the control pressure port and the inlet port, individually and also simultaneously. Non pressurized ports shall be open to return or to atmosphere. Proof pressure of 3000 psi shall be applied to the return port. The rate of applying pressure shall not exceed 25,000 psi per minute. The valve shall be filled with fluid and stabilized at 450±15°F for qualification tests. For acceptance tests, proof pressure tests shall be conducted at 95±15°F. The proof pressures shall be held for at least two minutes, and there shall be no evidence of external leakage, permanent set or other damage.

4.6.3 Leakage at Room Temperature.- With a test set up similar to Figure 2 the valve and fluid shall be stabilized at a temperature of 95°F±15°F. Pressure shall be applied to the valve in the sequence described below and the valve shall be actuated after each test:

a. Apply 4,000 psi to inlet port.

b. Apply 4,000 psi to inlet, outlet, and control ports.

c. Apply 4,000 psi to inlet and 2,000 psi to the return port.

In each case unpressurized ports shall be open and pressures shall be applied for ten minute periods. In each case the combined leakage from the open ports shall not exceed the values given in Table 1. External leakage shall be zero.

4.6.4 Function Test.

4.6.4.1 Function Test for Qualification.- The valve shall be adjusted to meet the requirements of setting No. 1 in Table II with 4000 psi on the inlet port. With a test set-up similar to Figure 3, apply rated flow and rated pressure to the inlet port and 50 psi to the return port. Cycle the valve by increasing control pressure to 4,000 psi and then reducing pressure to zero. After cycling valve, apply 4000 psi to the inlet port and gradually increase control pressure until the valve opens enough to allow rated flow from inlet to outlet at a net pressure drop across the valve equal to 25 psi or less. At this condition the valve shall be considered "full open." The control pressure at "full open" shall not exceed 1250 psi. Net pressure drop shall be determined as the difference in pressure drop across the housing with the valve installed and the pressure drop across the housing with the valve removed and the corresponding cavity plugged. Continue to increase control pressure until 4,000 psi is reached, then gradually reduce control pressure until valve shuts off flow from inlet to outlet. Shut-off position is recognized when leakage from inlet to outlet does not exceed the values given in Table I. Control pressure at shut-off shall not be less than 900 psi. Without changing the adjustment repeat the above procedure with return pressure increased to 400 psi. Upon increasing control pressure the valve shall move to "full open" position at 1600 psi

maximum. Upon decreasing pressure the valve shall shut off at 1250 psi minimum. Repeat the above procedure with the valve adjusted to meet the requirements of setting No. 2 in Table II.

4.6.4.2 Function Test for Acceptance.- The valves shall be adjusted to open at the control pressure specified in the procurement document when delivered to the procuring agency. The valves shall be acceptance tested for proper functioning per 4.6.4.1 except that the control pressure at full open shall not exceed that specified in the procurement document. Control pressure at shut-off shall not be less than 350 psi below the control pressure at full open as specified in the procurment document. The return pressure to be used in this test shall also be as specified in the procurement document.

4.6.5 Extreme Temperature Performance.

4.6.5.1 Low Temperature Functioning.- With a test set up similar to Figure 3, the valve and fluid shall be soaked for a minimum of 8 hours at -65°F or lower. While maintaining oil temperature at -65°F or lower, apply 50 psi to the return port and sufficient pressure to the inlet port (approximately 100 to 200 psi) to drive rated flow from inlet to outlet. Gradually apply 1250 psi to the control port. The valve shall open and rated flow shall flow from inlet to outlet with a net pressure drop across the valve not exceeding 100 psi. Continue increasing control port pressure to 4,000 psi. Net pressure drop with rated flow across the valve shall still not exceed 100 psi. Decrease control pressure to 900 psi. Flow from inlet to outlet shall cease. Increase pressure at inlet port to 4,000 psi. Leakage from inlet to outlet shall not exceed values given in Table I. Continue decreasing control pressure to zero.

Leakage from inlet to outlet shall not exceed values given in Table I. The temperature of the set up shall be allowed to warm up to -20±7°F. The -65°F function test above shall be repeated with the fluid and ambient temperature maintained at -20°F±7°F. Net pressure drop across the valve at rated flow shall not exceed 80 psi with oil temperature of -20°F±7°F. Leakage from inlet to outlet with valve in the shut-off position shall not exceed values given in Table I. The leakage test of 4.6.3 shall be repeated with the fluid and valve stabilized at a temperature of -20°F±7°F.

4.6.5.2 Rapid warm-up to 450°F.- The low temperature test set up shall be allowed to warm up rapidly to a temperature of 450°F. While the temperature is increasing and without waiting for it to stabilize throughout the setup, valve full-open and shut-off positions shall be checked. These checks shall be made at inlet fluid temperatures of approximately 60°F., 140°F., 220°F., 300°F., 380°F, and 450°F. Each check shall be made in the following manner: With 50 psi applied to the return port and 4,000 psi applied to the inlet port, gradually apply 1250 psi to the control port. The valve shall open and rated flow shall flow from inlet to outlet with a net pressure drop across the valve not exceeding 25 psi. The control pressure shall be further increased to 4,000 psi. Control pressure shall then be decreased to 900 psi. Flow from inlet to outlet shall cease. Leakage from inlet to outlet shall not exceed values given in Table I.

4.6.5.3 High Temperature Leakage.- Repeat the leakage test of paragraph 4.6.3 except the valve and fluid shall be stabilized at a temperature of 450°F±15°F.

4.6.6 Endurance Cycling.- With a test set-up similar to Figure 3, the valve shall be subjected to 20,000 functioning cycles at a rate of approximately 14 cpm. Each cycle shall consist of a pressure application of 4,000 psi to the actuation pressure port followed by a reduction of pressure to 500 psi or less. During

this test 4,000 psi shall be applied to the inlet port and flow through the valve shall be in the range indicated for Class 1, 2, and 3 valves, paragraph 3.4.11.1 and 1.2. The test shall be conducted while the valve and fluid undergoes a time-temperature spectrum as shown in Figure 4. The 20,000 cycles shall be accomplished by repeating the spectrum 4 times. The valve and fluid shall be soaked at -65°F or lower for 8 hours prior to each spectrum. After completion of the 20,000 cycles the valve shall undergo the leakage test, paragraph 4.6.3 and the leakage rate shall not exceed the leakage values given in Table I by more than 50 percent. During the cycling there shall be no seizing or binding of mating parts. The return line pressure shall be approximately 50 psi for the entire endurance cycling.

4.6.7 Vibration Test.

a. The full flow pressure adjustment shall be adjusted to each extreme adjustment position 15 times prior to this test. The valve shall then be adjusted to meet the requirements of setting No. 1 in Table II. With the fluid maintained at 95±15°F, the valve shall be cycled at a rate of approximately 14 cycles per minute. Cycling shall be accomplished by applying rated pressure to the pressure control port and then reducing pressure to zero. During this test 4,000 psi shall be applied to the inlet port. While the valve is being cycled it shall be vibrated in a horizontal direction for 20 minutes with frequency varying between 5 and 2000 cps. The amplitude shall be 0.04 inches (0.08 inch total excursion) or 15 G's, whichever is limiting. This frequency survey shall be repeated 2 times and the frequency of any and all resonant points (natural frequencies) shall be noted. Vibrate the valve for 90 minutes at the most severe resonant frequency noted above at 0.08 inch total excursion or 15 G's

whichever is less severe. If no resonant vibration is noted, vibrate the valve at 500 cps. At 23 minute intervals during this 90 minute test and at a frequency 10 percent above or below the natural frequency, a check shall be made to assure that the full flow pressure setting has not changed more than 1 percent from the original setting.

b. Repeat (a) changing the direction of vibration 90° horizontally.

c. Repeat (a) changing the direction of vibration to vertical.

d. After completion of (a), (b), and (c), the valve shall be checked per paragraph 4.6.3 except that the allowed internal leakage may be increased 50 percent. The test of 4.6.4.1 shall be performed and the operational requirements therein satisfied.

e. The valve shall then be removed from the manifold and visually inspected for any mechanical failure or excessive wear.

4.6.8 Burst Pressure.- With the outlet flow port plugged, pressure shall be applied to both the inlet port and the control pressure port simultaneously at a rate not to exceed 25,000 psi per minute until 10,000 psi is reached. This pressure shall be held for two minutes without rupture of internal or external parts. The fluid temperature shall be 95±15°F for this test. Apply 5000 psi to the return port at the same rate and hold for 2 minutes. The valve shall be removed from the test manifold and visually inspected for any mechanical failures.

5. PREPARATION FOR DELIVERY

5.1 Preservation and Packaging.- Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior

to sealing. The component shall then be wrapped or bagged in grade A greaseproof paper conforming to Specification MIL-B-121 and sealed with tape conforming Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of Shipments.- Interior packages and exterior shipping containe shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document

Name of part

MS Part No.

Month and year of manufacture

Class or size

6. NOTES

6.1 Intended Use.- The pressure operated shut off valves covered by this specification and intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891, and operating with hydraulic fluid conforming to Specification MIL-H-8446 at pressures which do not exceed 4,000 psi. The shut off valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering Data.- Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number

(c) Class

(d) Federal stock number

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. Naval Air Material Center, Naval Base, Philadelphia 22, Pennsylvania.

Custodians:
Navy - Bureau of Naval Weapons
Air Force

Preparing activity:
Navy - Bureau of Naval Weapons

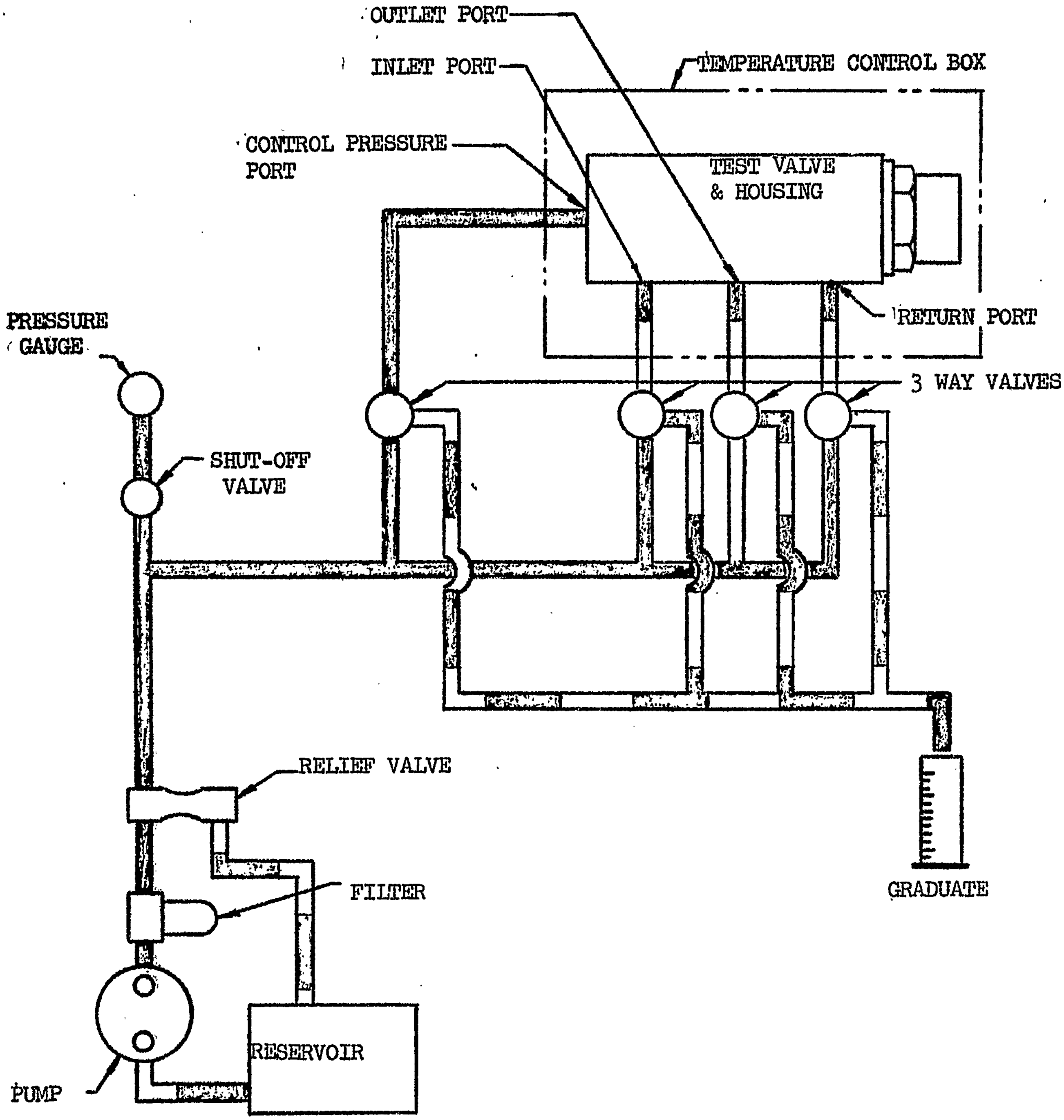


FIGURE 2

TYPICAL SET-UP FOR PROOF & LEAKAGE TEST

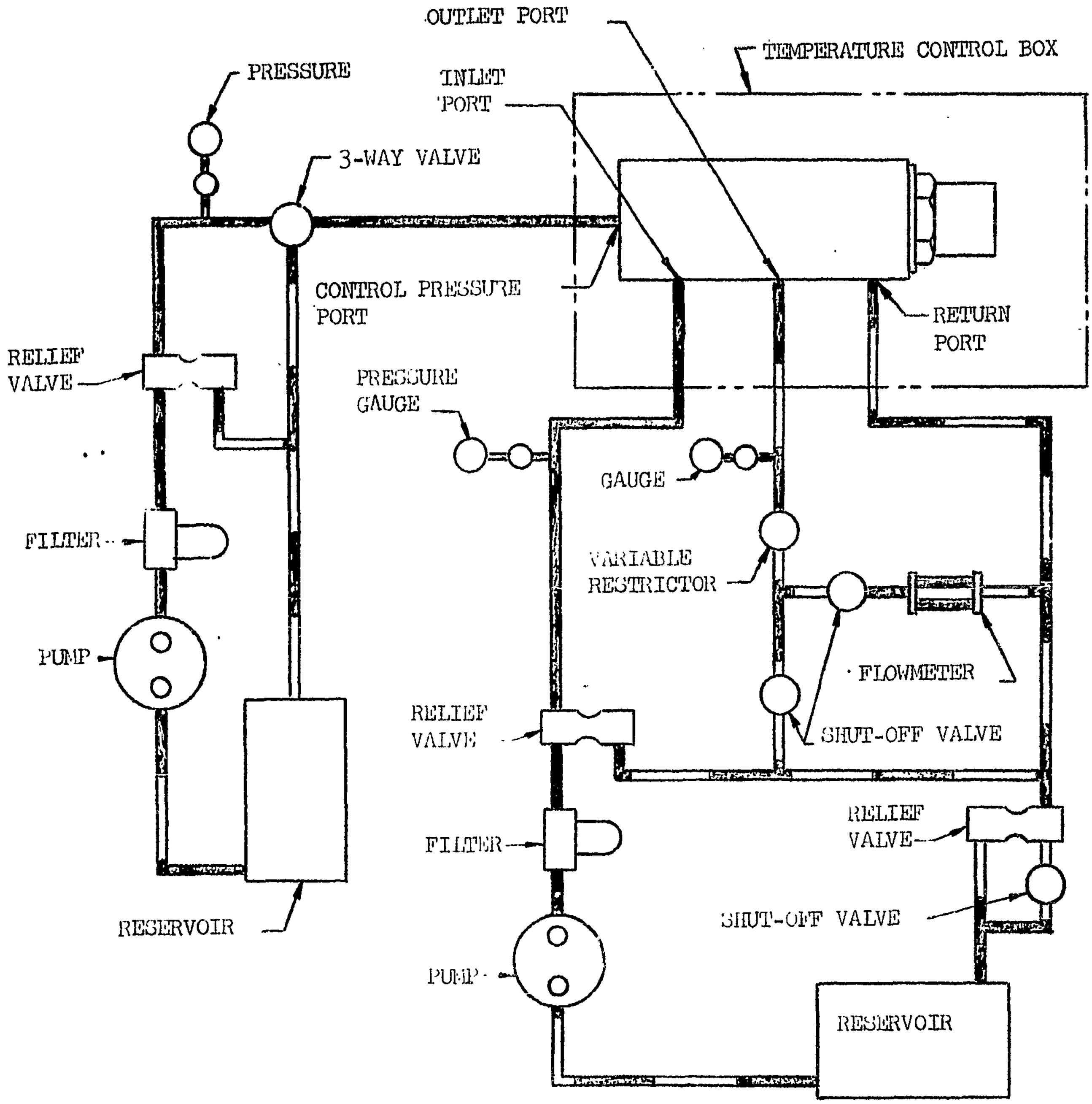


FIGURE 3

TYPICAL SET-UP FOR FUNCTIONING, ENDURANCE, AND PRESSURE DROP TEST

NOTES:

1. Rate of temperature rise or decay may vary within the shaded areas shown.
2. Approximately six and one half hours of endurance cycling are to be run in one day.
3. The ambient temperature shall be maintained between 450 - 550°F during the time from the 2nd hour through 5 1/2 hours of the spectrum shown.

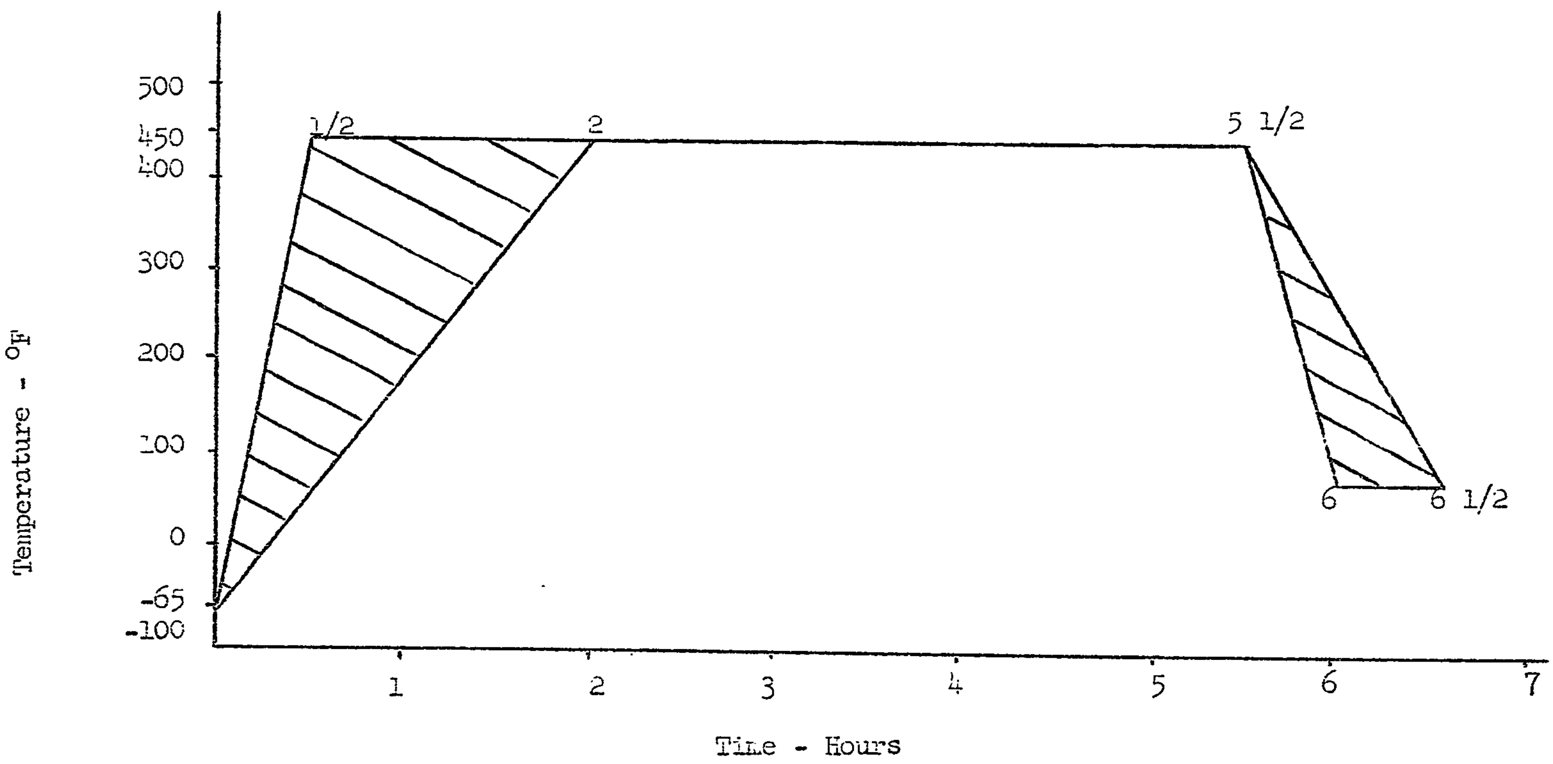
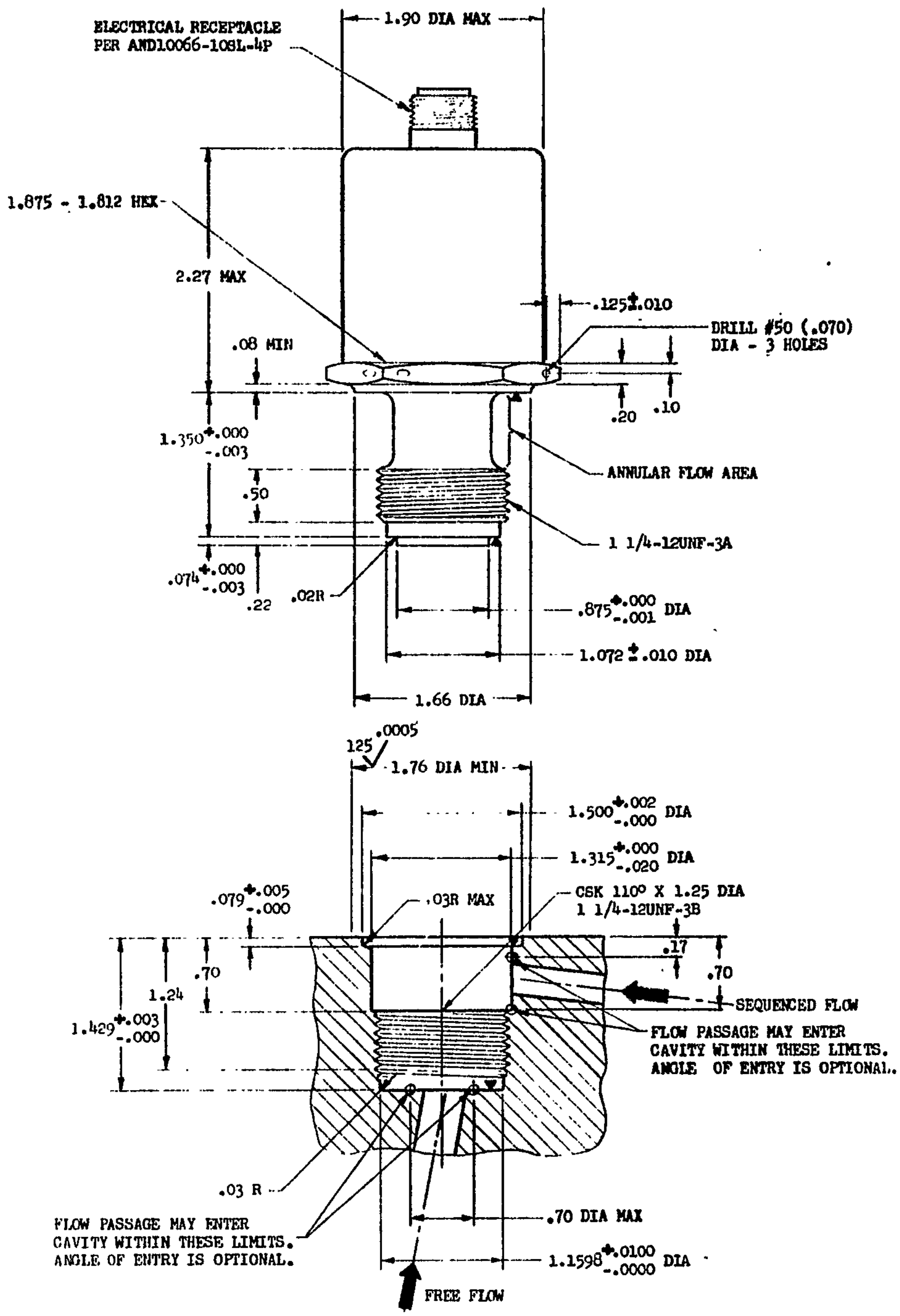


FIGURE 4

APPENDIX VIII

Suggested MIL Specification for Solenoid Operated Sequence Valve
Suggested MS Standard for Solenoid Operated Sequence Valve

FED. SUP CLASS



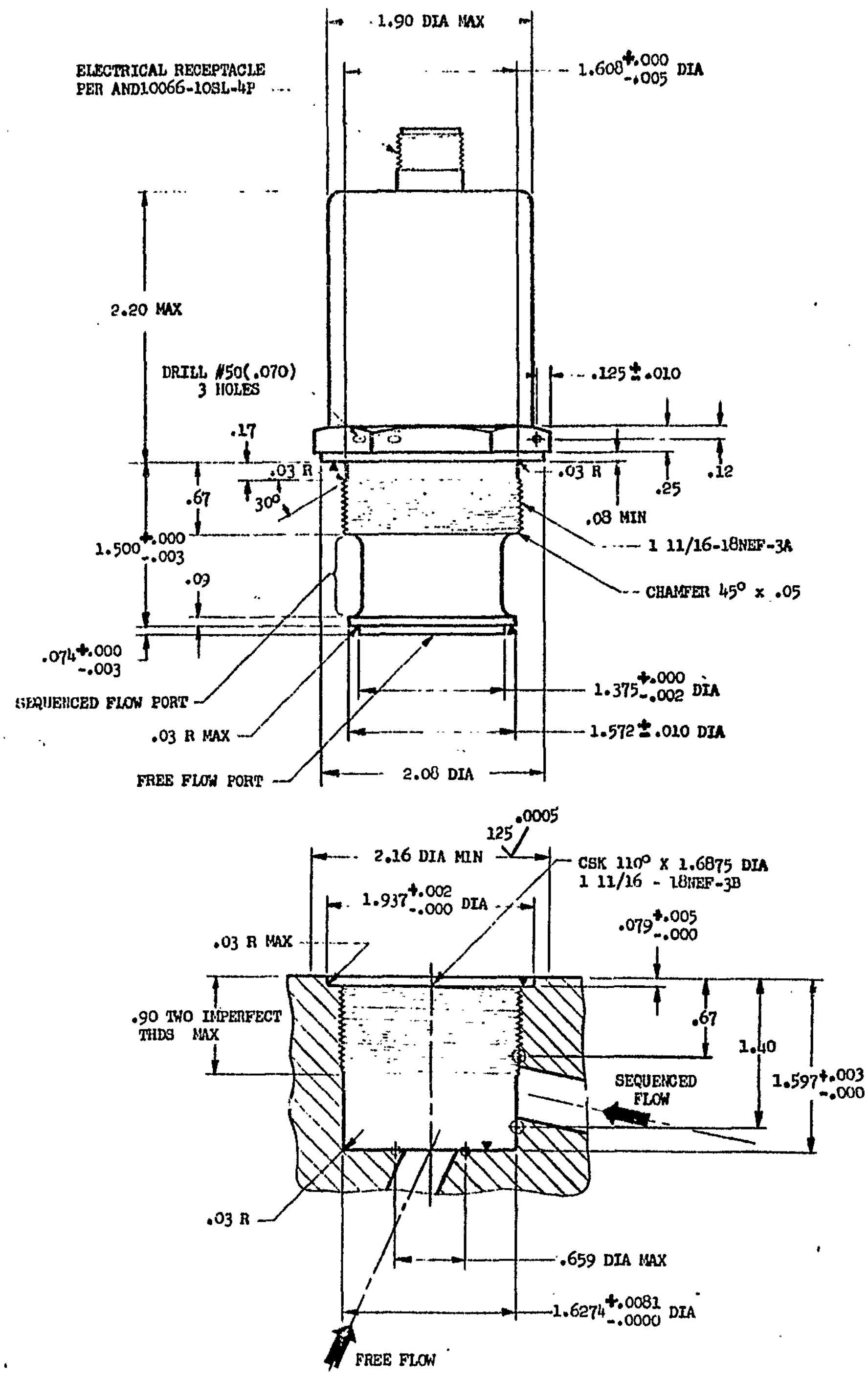
-1 VALVE

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE VALVE, MODULAR HYDRAULIC SOLENOID OPERATED SEQUENCE 4,000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 3

FED. SUP CLASS



-2 VALVE

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC SOLENOID OPERATED SEQUENCE** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 3

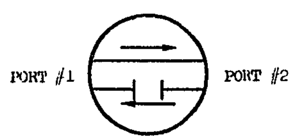
FED. SUP CLASS

PART NUMBER	RATED FLOW	WEIGHT (MAX)
MS -1	12 GPM	
MS -2	25 GPM	1.50 POUNDS

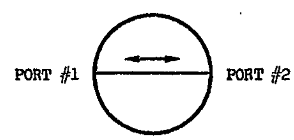
DETAIL REQUIREMENTS

TEMPERATURE LIMITS: 450°F FLUID AND 650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE: OPERATING 4000 PSI, PROOF 6,000 PSI, BURST 10,000 PSI
FLUID: SPECIFICATION MIL-H-8446
SEALS: SPECIFICATION MIL-
LIFE: SEE SPECIFICATION MIL- FOR ENDURANCE.
PRESSURE DROP: 50 PSI MAXIMUM AT RATED FLOW

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16/RHR. ALL OTHER SURFACES SHALL BE 125/ UNLESS OTHERWISE NOTED.
TOLERANCES: THE TWO SEALING SURFACES ON THE VALVE SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THE AXIS OF VALVE THREAD WITHIN .003 FIR. THE TWO SEALING SURFACES IN THE VALVE CAVITY SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THE AXIS OF THE CAVITY THREAD WITHIN .003 FIR. SURFACES DEFINED BY 1.76 DIAMETER ON -1 VALVE CAVITY AND DIAMETER ON -2 VALVE CAVITY SHALL BE PERPENDICULAR TO THE RESPECTIVE AXIS OF THE CAVITY THREAD WITHIN .001 FIR.
LINEAR TOLERANCE: UNLESS OTHERWISE NOTED ±.01 INCH.
ANGULAR TOLERANCE: UNLESS OTHERWISE NOTED ± 2°.
THIS VALVE IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4,000 PSI, TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL . THE ELECTRICAL POWER USED TO ENERGIZE THE VALVE SHALL BE DIRECT CURRENT IN ACCORDANCE WITH SPECIFICATION MIL-E-7894ASG.
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO MIL-S-7742.
THE APPLICABLE MS PART NUMBER, THE WORDS "SEQUENCE VALVE", THE RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON A NAMEPLATE OR DIRECTLY ONTO THE SOLENOID SO THAT THE IDENTIFICATION IS VISIBLE WHEN THE VALVE IS INSTALLED.
THE VALVE IS TO FUNCTION AS SHOWN IN THE FOLLOWING SCHEMATIC.



DE-ENERGIZED



ENERGIZED

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC SOLENOID OPERATED SEQUENCE** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 3 OF 3

MILITARY SPECIFICATION
VALVE: AIRCRAFT HYDRAULIC SOLENOID OPERATED SEQUENCE

1. SCOPE

1.1 Scope.- This specification covers cartridge-type, modular hydraulic, solenoid operated, sequence valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Solenoid operated sequence valves shall be of the following classes:

Class I - 0 to 4 gallons per minute capacity
Class 2 - 0 to 12 gallons per minute capacity
Class 3 - 0 to 25 gallons per minute capacity

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified:

Specifications

Federal

PPP-T-60 Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible, Waterproofed
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection Process, Magnetic-Particle
MIL-H-6875	Heat Treatment of Steels (Aircraft Practice) Process for
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-E-7894	Electrical Power, Aircraft, Characteristics of
MIL-M-7911	Marking, Identification of Aeronautical Equipment, Assemblies and Parts
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III Design, Installation, Tests and Data Requirements, General Specification for
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specification and Standards, Use of
MS-33540	Safety Wiring - General Practices for
MS-20995	Wire-Lock
STD. No. 151	Federal Test Method; Metals, Test Methods

Specifications (Cont)

Drawing

MS- Valve, Solenoid Operated Sequence, Modular, Envelope for

2.2 Other publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in the order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification.- The sequence valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes.- Materials and processes used in the manufacture of these valves shall conform to the following requirements and to applicable specifications as defined in Section 2.

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion during the normal service life of the valve which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency. Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition,

cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel.- Close-fitting, sliding steel parts shall be cold stabilized in accordance with specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts.- Plastic parts shall be used only with the approval of the procuring agency for each application.

3.3 Parts.- Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the contractor's drawings.

3.4 Design and construction

3.4.1 Envelope.- The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification, MS _____ and applicable drawings.

3.4.2 Hydraulic fluid.- The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range.- The valves shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F, when tested per 4.6.10.

3.4.4 Threads.- Only class 3 thre   conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals.- Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with Standard Drawings MS-33540 and MS-20995.

3.4.7 Retainer rings.- Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valve.

3.4.8 Structural strength.- The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight.- The weight shall be kept to a minimum consistent with good design, and shall be specified on the applicable drawing.

3.4.10 Mounting position.- The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control.- The valves shall be designed to pass rated flow per 1.2.

3.4.12 Surface roughness.- Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.4.13 Alignment.- All plungers, poppets, balls, pistons, etc., shall be guided to prevent misalignment or chattering on their seats.

3.4.14 Air entrapment.- Entrapment of air within the valve shall not change the performance requirements of the valve.

3.4.15 Dielectric strength.- The valve electrical solenoid shall have sufficient dielectric strength to withstand without damage 600 volts root mean square between the solenoid and ground, when tested per 4.6.8.

3.4.16 Salt spray.- The valves shall be capable of satisfactory operation after 100 hours of exposure to salt spray, when tested per 4.6.13.

3.5 Interchangeability

3.5.1 Manufacturer's parts.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification.- Each valve shall have the identifying markings placed on the hex head or the flange so that the identification can be read when the valve is installed in a manifold cavity. Each valve shall be permanently and legibly marked with the following information, per MIL-M-7911.

Valve, Solenoid Operated Sequence
MS No.
Manufacturer's Part No.
Manufacturer's Name or Trademark

In addition, the pressure setting shall be stamped into a metal tag which

is attached to the safety wire securing the adjustment or adjustment cover.

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contaminant. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection.- All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated pressure.- The valves shall be designed to operate satisfactorily in a hydraulic system having a rated pressure of 4,000 psi, when tested per 4.6.3.

3.8.2 Operating pressure.- The valves shall be designed to insure satisfactory operation and service life throughout the operating range of 0 to 4,000 psi, when tested per 4.6.3. The valves shall be capable of operation at 6,000 psi.

3.8.3 Proof pressure.- The valves shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.2 and there shall be no evidence of external leakage, permanent set, or other damage.

3.8.4 Burst pressure.- The valves shall be designed so as not to burst at any pressure below 10,000 psi. when tested per 4.6.15.

3.8.5 Solenoid.- The solenoid shall be a continuous duty type, single coil construction, compact design, and so constructed that hydraulic fluid can not contact the electrical windings.

3.8.5.1 Valve operation

3.8.5.1.1 Sequence flow.- Sequence flow shall be from pressure port to cylinder port. Energizing the valve shall cause sequence flow and de-energizing the valve shall block sequence flow. Sequence flow pressure shall not exceed cylinder port pressure more than 100 psi and a maximum differential pressure of 50 psi shall be sufficient to maintain rated flow, when tested per 4.6.3 and 4.6.5.

3.8.5.1.2 Free flow.- Free flow shall be from cylinder port to pressure port with the valve in either the energized position or de-energized position. A maximum differential pressure of 25 psi shall be sufficient to maintain free flow, when tested per 4.6.3 and 4.6.5.

3.8.5.2 Electrical characteristics

3.8.5.2.1 Electrical power.- The valves shall be designed for satisfactory operation in a nominal 28 volt direct current system and shall meet the direct current requirements of Specification MIL-E-7894. The valves shall be capable of satisfactory operation at 18 volts direct current when differential pressures from 100 psi to 4,000 psi are applied across the valve, when tested per 4.6.3 and 4.6.5.

3.8.5.2.2 Current drain and time lapse.- With an applied voltage of 28 volts direct current, the current drain shall not exceed 1.0 ampere at 95°F ambient temperature, when tested per 4.6.7. The time lapse between electrical application and pressure rise to 4,000 psi shall not exceed 0.1 second, when tested per 4.6.9.

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3.8.6 Leakage.- Internal and external leakage shall not exceed the values in Table I, when tested per 4.6.4.

TABLE I
VALVE LEAKAGE

VALVES CLASS	PRESSURE PSI	MAX. INTERNAL DROPS/MIN	MAX. EXTERNAL DROPS/MIN
1, 2, and 3	5 4,000	10 10	0 0

3.8.7 Surge pressure.- The valves shall be capable of satisfactory operation when 6,000 psi surge pressure is applied and the leakage values of Table I shall not be exceeded, when tested per 4.6.6.

3.8.8 Endurance.- The valves shall be capable of satisfactory operation after 20,000 cycles of operation, when tested per 4.6.11.

3.8.9 Vibration.- The valves shall be capable of withstanding vibration from 5 to 2,000 cps at an amplitude of 0.04 inches (0.08 inch total excursion) or 15G whichever is limiting, in each of the three mutually perpendicular planes, when tested per 4.6.12.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.- The manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the procuring agency. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests.- The inspection and testing of sequence valves shall be classified as follows:

(a) Qualification tests
(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of sequence valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Tests.- The qualification tests shall consist of the following test which shall be conducted in the order listed.

(a) Examination of product per 4.6.1
(b) Proof pressure per 4.6.2
(c) Actuation per 4.6.3
(d) Pressure drop per 4.6.5
(e) Surge pressure per 4.6.6
(f) Solenoid current drain per 4.6.7
(g) Dielectric strength per 4.6.8
(h) Timing test per 4.6.9
(i) Leakage per 4.6.4
(j) Extreme temperature performance per 4.6.10
(k) Endurance per 4.6.11
(l) Vibration per 4.6.12
(m) Salt spray per 4.6.13
(n) Burst pressure per 4.6.14

4.4 Acceptance tests.- Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the valves or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

(a) Examination of product per 4.6.1
(b) Proof pressure per 4.6.2
(c) Leakage per 4.6.4
(d) Actuation per 4.6.3

4.5 Test conditions

4.5.1 Test fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95 ± 15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination.- Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of Particle	Percent by Weight of Total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	18 ± 3
over 40 micron	9 ± 3

4.5.4 Filtration.- The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity and which is acceptable to the procuring agency.

4.5.5.2 Acceptance test housing.- The tests in 4.4 may be conducted in the qualification test housing or in a housing having other external configuration.

4.6 Test methods

4.6.1 Examination of product.- Each valve shall be carefully examined to determine conformance with the requirements of this specification for workmanship, marking, conformance to applicable drawings, and for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Proof pressure.- With the valve de-energized apply 6,000 psi to the pressure port for two minutes. With the valve de-energized plug the pressure port and apply 6000 psi to the cylinder port for two minutes. The rate of applying pressure shall not exceed 25,000 psi per minute. For acceptance testing, proof pressure tests shall be conducted at 95 ± 15°F. For qualification testing, proof pressure tests shall be conducted with the valve and fluid stabilized at 450 ± 15°F. There shall be no external leakage, permanent set, or other damage resulting from proof pressure tests.

4.6.3 Actuation.- The valve shall be cycled 25 times by energizing and de-energizing the solenoid with an 18 volt source of direct current while 1500 psi is applied to the outlet port and at the end of each 5 cycles the valve shall be unseated by reversing flow through the valve. Repeat above procedure 25

additional times with 4000 psi applied to the outlet port. Repeat above procedure with 6000 psi applied to the outlet port and 28 volts to energize the solenoid. During this test, general functioning of the valve, relation between energized and de-energized position with opening and closing of valve shall be in accordance with paragraph 3.8.5 of this specification.

4.6.4 Leakage.- The test shall be performed with the valve held in the vertical position. The inlet port shall be positioned so that the force of gravity will act against the valve checking action. The valve shall be tested for internal and external leakage. Pressures of 5 psi maximum and 4000 psi shall be applied to the outlet(with the valve de-energized) port for a minimum period of 5 minutes each. The valve poppet shall be unseated between each pressure application. In each case the leakage measurement period shall consist of the last 3 minutes of the 5 minutes period. The rate of internal leakage shall not exceed the values specified in Table I. There shall be no external leakage during this test.

4.6.5 Pressure Drop.- For the rated flow of each class valve, determine the pressure drop between the inlet and the outlet port (free flow direction) with the solenoid de-energized. With the solenoid energized determine the pressure drop at rated flow from the outlet to the inlet ports. A back pressure of 200 psi, minimum shall be maintained on the downstream side of the valve. This test shall be run at a fluid temperature of $95^{\circ} \pm 15^{\circ}$F and the sequence flow pressure drop through the valve shall not exceed 50 psi and the free-flow pressure drop shall not exceed 25 psi. The pressure drop shall not include the pressure drop through the test manifold or housing.

4.6.6 Surge Pressure.- The surge pressure test shall be performed at a temperature of $95^{\circ} \pm 15^{\circ}$F. The test shall be set up as shown in Figure 1. The

The inlet port shall be open and the test valve shall be in the de-energized position. The directional control valve shall allow pressure to build-up to 6000 psi in the accumulator with the test valve outlet port vented to return. The directional control valve shall be quickly actuated to permit surge pressure to the outlet port. The test valve shall receive 25 such applications of surge pressure. The valve shall show no signs of leakage exceeding the values given in Table I.

4.6.7 Solenoid current drain.- Apply 28 volts direct current to solenoid. The current drain required to energize the solenoid shall not exceed 1.0 ampere at $95^{\circ} \pm 15^{\circ}$F.

4.6.8 Dielectric strength.- The solenoid shall be soaked at not less than 650°F for 8 hours or longer and held at 650°F while 600 volts root mean square is applied between the solenoid and ground for a period of 60 seconds. There shall be no failure or evidence of damage to insulation.

4.6.9 Timing test.- An oscillograph shall be used to plot electrical input to the solenoid and pressure at the inlet port, simultaneously. With 4000 psi applied to the outlet port energize the solenoid. The time lapse between electrical application and pressure rise to 4000 ± 50 psi at the inlet port shall not exceed 0.1 second. The temperature shall be $95^{\circ} \pm 15^{\circ}$F for this test.

4.6.10 Extreme temperature performance.

4.6.10.1 Low temperature operation.- The test set up shall be similar to Figure 1. The test set-up shall be soaked at a temperature not warmer than -65°F for 8 hours or longer. At the end of this period 1500 psi shall be applied to the outlet port, the solenoid shall be energized by an 18 volt source of electricity and the valve shall open and permit flow from outlet to inlet. The solenoid shall then be de-energized and 4000 psi applied to the outlet port The voltage

to the solenoid shall be increased and the coil voltage that will fully open the valve shall not exceed 18 volts. The solenoid voltage shall be decreased and coil voltage at which the valve fully closes shall be recorded. The temperature shall then be raised to -20°F and the above procedure repeated. After completion of the above test and the temperature held not warmer than -20°F the pressure shall be increased to 6000 psi. The voltage required to fully open the valve shall then be determined and this value shall not exceed 28 volts. Decrease the solenoid voltage and determine the coil voltage at which the valve will fully close.

4.6.10.2 Rapid warm up.- The test set-up for the low temperature test shall be used for this test. With valve "A" closed apply a pressure of 4000 psi to the outlet port of the test valve. The fluid shall be warmed up rapidly from -20°F by flowing through the relief valve. When the fluid temperature reaches +74°F the solenoid shall be energized with a maximum of 18 volts for 5 seconds. This shall permit rated flow to pass through the valve. At the end of 5 seconds the solenoid shall be de-energized. The above procedure shall be repeated when the fluid temperature reaches 168, 262, 356 and 450°F. At each of these checks the test valve shall fully open each time the solenoid is energized and shall fully close each time the solenoid is de-energized.

4.6.10.3 High temperature operation and leakage.- The test set up shall be similar to Figure 1. With the system bled of air and pressurized at 4000 psi, temperature in the temperature controlled box shall be maintained at 450°F minimum for not less than 6 hours. The valve shall be de-energized during this period. At the end of this period and with 4000 psi applied to the outlet port the solenoid shall be energized. The coil voltage required to open the valve shall not be greater than 18 volts. The coil voltage shall be decreased and the voltage at which the valve fully closes shall be recorded. Repeat this procedure for five

complete cycles. No long waiting period between operations is necessary. Leakage test shall be performed per paragraph 4.6.4 except that the allowable leakage shall be 6.5 cc/min while the valve is at a temperature of 450°F. There shall be no external leakage during this test.

4.6.11 Endurance. - The test set-up shall be similar to Figure 1. The valve shall be subjected to a total of 20,000 cycles of opening and closing by energizing and de-energizing the solenoid while a pressure of 4000 psi is applied to the outlet port so that rated flow will pass through the valve during endurance. The endurance test shall be conducted while the valve undergoes a time-temperature spectrum as shown in Figure 2. The 20,000 cycles shall be accomplished by going through the spectrum four times. The valve shall be cycled at the rate of 12 to 16 cycles per minute. Prior to going through a spectrum, the valve and fluid shall be maintained at a temperature not warmer than -65°F for 8 hours or longer. After completing the four spectrums the valve shall be tested and shall meet the requirements as specified in paragraph 4.6.4. No external leakage shall occur during the duration of this test. With a 250 psi differential pressure between outlet and inlet ports the valve shall be closed when de-energized. The valve shall be energized and shall open and pass rated flow.

4.6.12 Vibration Test

(a) With the fluid temperature maintained at 95 ± 15°F the valve shall be cycled at a rate of 12 to 16 cpm. Cycling shall be accomplished by energizing and de-energizing the solenoid so as to produce alternately rated flow and no flow from outlet to inlet of the valve. While the valve is being cycled it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2000 cps in 30 minutes. The amplitude shall be 0.0[illegible]ches (0.08 inch total excursion) or 15G whichever is limiting. This test shall be repeated two times and during this time the frequency of any and all resonant points shall be noted. Vibrate

the valve for 90 minutes at the most severe resonant frequency noted above at 0.08 in. total excursion or 15G whichever is less severe. If no resonant frequency is found, the valve shall be vibrated at 500 cps for 90 minutes.

(b) Repeat (a) changing the direction of vibration 90° horizontally.

(c) Repeat (a) changing the direction of vibration to vertical.

(d) After completion of (a), (b) and (c) the valve shall be checked per paragraph 4.6.4 except that the allowable leakage shall be increased by 50 percent.

(e) The valve shall then be removed from the manifold and visually inspected for any mechanical failures.

With a 250 psi differential pressure between outlet and inlet ports the valve shall be closed when de-energized. The valve shall be energized and shall open and pass rated flow.

4.6.13 Salt Spray Test.- The valve shall be subjected to a 100 hour salt spray test in accordance with Federal Test Method Standard No. 151, Method 811. At the conclusion of this test period, the solenoid shall be air dried for 6 hours then subjected to a dielectric test per paragraph 4.6.8. With 4000 psi applied to the pressure port the valve shall be energized with no more than 18 volts and the valve shall open and pass rated flow.

4.6.14 Burst Pressure Test.- Pressure shall be applied to the outlet port at a rate not to exceed 25,000 psi per minute until 10,000 psi is reached. This

pressure shall be held for at least two minutes. There shall be no rupture of external or internal parts. The fluid temperature shall be 95 ± 15°F for this test. Repeat the above test with the outlet port plugged and pressure applied to the inlet port.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging.- Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments.- Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document
Name of part
MS Part No.
Month and year of manufacture
Class or size

6. NOTES

6.1 Intended use.- The sequence valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891 and operating with hydraulic fluid conforming to Specification MIL-H-8446. The valve is further intended for use in a manifold or packaged type system.

6.2 Ordering data.- Procurement documents should specify the following:

Title, number, and date of this specification
MS part number
Class
Federal Stock number
Pressure setting

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any wa supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacturer, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

Preparing activity:

Navy - Bureau of Naval Weapons

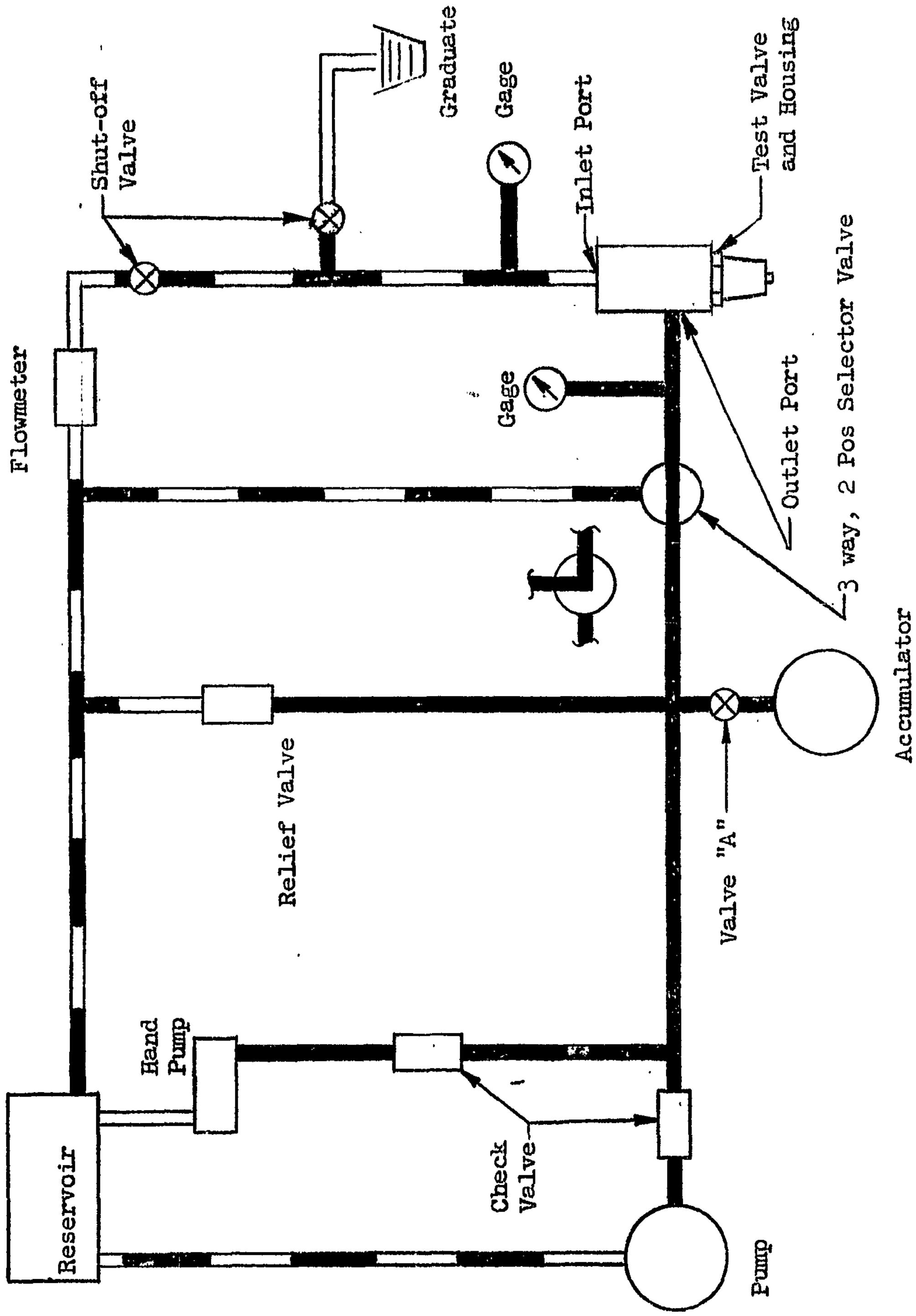

Shut-off Valve
Graduate
Gage
Inlet Port
Test Valve and Housing
3 way, 2 Pos Selector Valve
Outlet Port
Flowmeter
Gage
Accumulator
Relief Valve
Valve "A"
Hand Pump
Check Valve
Reservoir
Pump

FIGURE 1

Notes:
1. Rate of temperature rise or decay may vary within the shaded areas shown.
2. Approximately six hours of endurance cycling are to be run in one day.
3. Ambient temperature shall be maintained at 650°F during the time from the 2nd hour through the 5th hour of the spectrum shown.

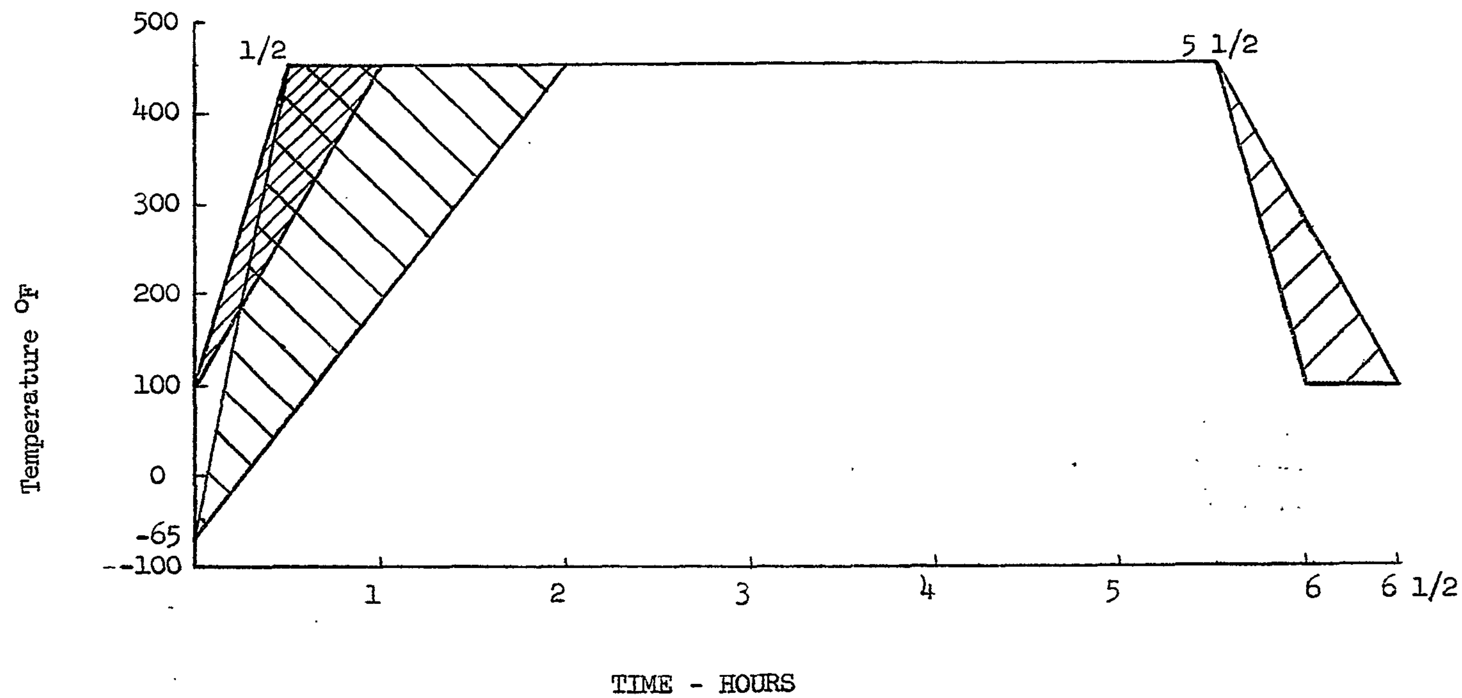


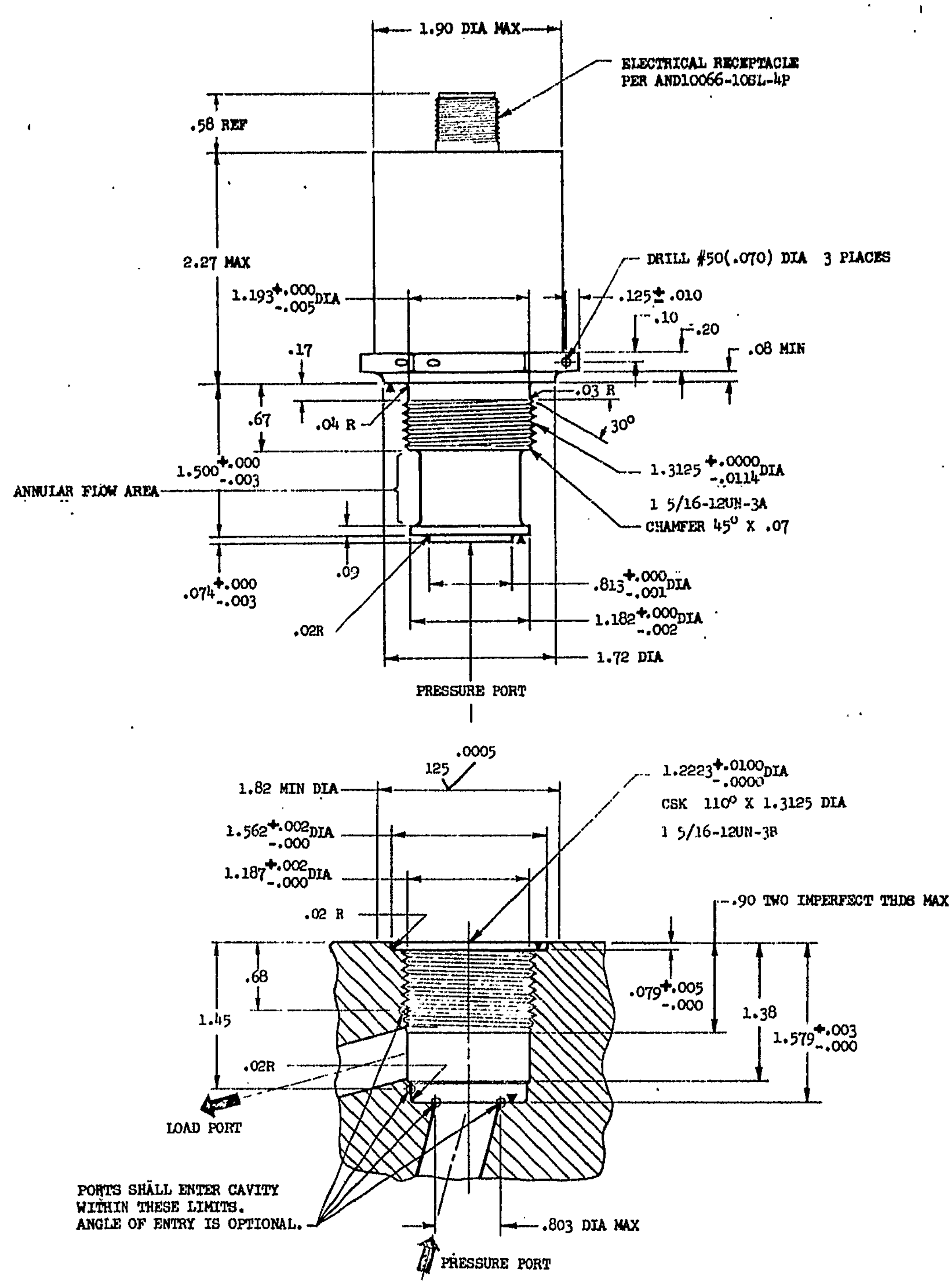
FIGURE 2

APPENDIX IX

Suggested MIL Specification for Solenoid Operated Shut-Off Valve

Suggested MS Standard for Solenoid Operated Shut-Off Valve

FED. SUP CLASS



REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC** SOLENOID OPERATED, TWO WAY, TWO POSITION SELECTOR 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

FED. SUP CLASS

DETAIL REQUIREMENTS

TEMPERATURE LIMITS: +450°F FLUID AND +650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE: OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI.
FLUID: SPECIFICATION MIL-H-8446.
SEALS: SPECIFICATION MIL-
LIFE: SEE SPECIFICATION MIL- FOR ENDURANCE.
PRESSURE DROP: 50 PSI MAXIMUM AT 25 GPM FLOW.

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 16/ RHR. ALL OTHER SURFACES 125/ RHR UNLESS OTHERWISE NOTED.
TOLERANCES: THE TWO SEALING SURFACES ON THE VALVE SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THE AXIS OF VALVE THREAD WITHIN .003 FIR. THE TWO SEALING SURFACES IN THE VALVE CAVITY SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THE CAVITY THREAD AXIS WITHIN .003 FIR. SURFACE DEFINED BY 1.82 DIAMETER ON FACE OF CAVITY SHALL BE PERPENDICULAR TO AXIS OF CAVITY THREAD WITHIN .001 FIR.
LINEAR TOLERANCE: UNLESS OTHERWISE NOTED ±.01.
ANGULAR TOLERANCE: UNLESS OTHERWISE NOTED ±2°.
THIS VALVE IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- . THE ELECTRICAL POWER USED TO ENERGIZE THE VALVE SHALL BE DIRECT CURRENT IN ACCORDANCE WITH SPECIFICATION MIL-E-7894ASG.
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE APPLICABLE MS PART NUMBER, THE WORDS "TWO WAY, TWO POSITION SELECTOR VALVE", 25 GPM RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON A NAMEPLATE OR DIRECTLY ONTO THE SOLENOID SO THAT THE IDENTIFICATION IS VISIBLE WHEN THE VALVE IS INSTALLED.
THE VALVE IS TO FUNCTION ACCORDING TO THE FOLLOWING SCHEMATIC:

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC** SOLENOID OPERATED, TWO WAY, TWO POSITION SELECTOR 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION

VALVE: AIRCRAFT HYDRAULIC SOLENOID OPERATED SHUT-OFF

1. SCOPE.- This specification covers a cartridge-type, modular hydraulic solenoid operated shut-off valve, with a 0 to 25 GPM rated flow at 4,000 psi, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible Waterproofed
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection Process, Magnetic-Particle
MIL-H-6875	Heat Treatment of Steels (Aircraft Practice) Process for
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-E-7894	Electrical Power, Aircraft Characteristics of
MIL-M-7911	Marking, Identification of Aeronautical Equipment, Assemblies and Parts
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft

MIL-H-8891	Hydraulic Systems, Type III Design, Installation, Tests and Data Requirements, General Spceification for
MIL-D-70327	Drawings, Engineering and Associated Lists
Standards	
Federal Test Method Standard 151	Metals; Test Methods
MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specification and Standards, Use of
MS-33540	Safety Wiring - General Practices for
MS-20995	Wire-Lock
Drawing	
MS-	Valve, Shut-Off, Solenoid Operated, Modular Envelope For

2.2 Other Publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification - The shut-off valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and Processes - Materials and processes used in the manufacture of the valve shall conform to the following requirements and to the applicable specifications as defined in Section 2.

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion, during the normal service life of the valve, which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency. Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel - Close-fitting, sliding steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts.- Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts.- Standard parts selected in accordance with section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws,

bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the manufacturer's drawings.

3.4 Design and construction

3.4.1 Envelope - The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification and MS- .

3.4.2 Hydraulic fluid - The valve shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range - The valve shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F. There shall be no evidence of external leakage or chatter when tested per 4.6.10.

3.4.4 Threads - Only class three threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals - Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying - Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety-wire shall be applied in accordance with standard drawings MS-33540 and MS-20995.

3.4.7 Retainer Rings - Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valve.

3.4.8 Structural strength - The valve shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight - The weight shall be kept to a minimum consistent with good design, and shall be specified on the applicable drawing.

3.4.10 Mounting position - The valve shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control - The valve shall be designed to pass rated flow per paragraph 1 from inlet port to outlet. Flow shall be checked or blocked from outlet to inlet port.

3.4.12 Surface roughness - Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.4.13 Solenoid - The solenoid shall be of single coil construction, compact design, and of sufficiently rugged construction to withstand the mechanical shocks and stresses incident to its use in aircraft. Solenoids shall be designed for continuous duty with the solenoid totally enclosed and shall be so designed that the hydraulic fluid can at no time come in contact with the electrical windings. The solenoid shall operate with direct current in accordance with Specification MIL-E-7894.

3.5 Interchangeability

3.5.1 Manufacturer's parts - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability - The modular valve shall be a self-contained components such that a valve may be removed from one housing and inserted into another housing without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification - Each valve shall have the identifying markings placed so that the identification can be read when the valve is installed in the manifold cavity. Each valve shall be permanently and legibly marked with the following information per MIL-H-7911.

Valve, Shut-Off

MS-

Manufacturer's Part Number

Manufacturer's Name or Trademark

3.7 Workmanship

3.7.1 Quality - Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contamination. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection - All magnetizable highly stressed parts shall be subjected to magnetic inspection per Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection per Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated flow and operating pressure - The valve shall be designed to insure satisfactory operation and service life at a rated flow of 0 to 25 gallons per minute at an operating pressure of 4,000 psi, when tested per 4.6.3. The valve shall be capable of operation at 6,000 psi.

3.8.2 Proof pressure - The valve shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.2. There shall be no evidence of external leakage, permanent set or other damage.

3.8.3 Burst pressure - The valve shall be capable of withstanding a burst pressure 10,000 psi, when tested per 4.6.14. There shall be no evidence of rupture of internal or external parts.

3.8.4 Valve operation -

3.8.4.1 Positions - The valve shall be closed in the de-energized position and shall be open in the energized position when tested per 4.6.3. Refer to Figure 1.

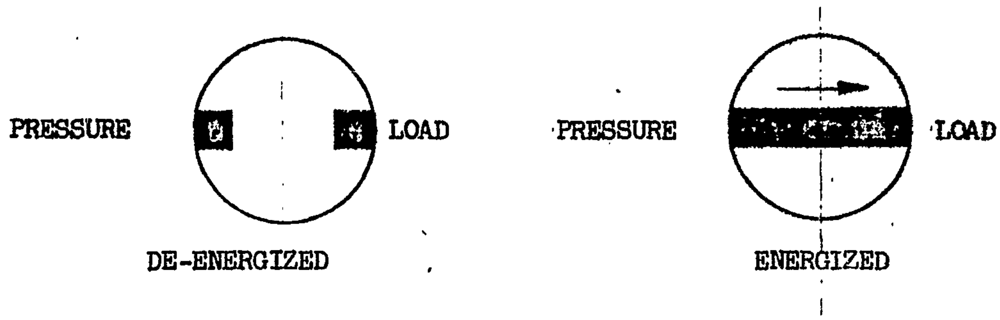


FIGURE 1

3.8.4.2 Pressures.- The valve shall operate with a pressure differential of 50 psi between the pressure port and cylinder port at rated pressure and proof pressure when tested per 4.6.2 and 4.6.3.

3.8.4.3 Electrical characteristics

3.8.4.3.1 The valve shall be designed for a 28 volt direct current system and shall be capable of satisfactory operation when 18 volts is applied at 4,000 psi and when 28 volts is applied at 6,000 psi throughout the ambient and operating temperature ranges, when tested per 4.6.10.

3.8.4.3.2 With 28 volts direct current applied to the coil terminals, the peak current drain shall not exceed 1.0 ampere when tested per 4.6.7.

3.8.4.3.3 The time lapse between energizing the solenoid and the pressure switch actuation shall not exceed 0.10 second when tested per 4.6.9.

3.8.4.3.4 There shall be no breakdown of the dielectric material of the solenoid that could cause damage or coil failure when 600 volts rms is applied per 4.6.8.

3.8.5 Internal leakage.- With the valve closed, in the de-energized position, the maximum allowable leakage shall be 6cc per minute, when tested per 4.6.4.

3.8.6 Pressure drop - The pressure drop through the valve shall not exceed 50 psi when tested per 4.6.5. This pressure drop shall not include the pressure drop through the test manifold or housing.

3.8.7 Surge pressure - The valve shall be capable of withstanding the surge pressure of paragraph 4.6.6. The total leakage of the valve shall not exceed 12cc when tested per 4.6.4.

3.8.8 Endurance - The valve shall be capable of satisfactory operation for a total of 20,000 cycles at a rate of 12 to 16 cycles per minute when tested per 4.6.11.

3.8.9 Vibration - The valve shall be capable of withstanding vibration from 5 to 2,000 cps at an amplitude of 0.04 inches (0.08 inch total excursion) or 15G whichever is limiting, in each of the three mutually perpendicular planes when tested per 4.6.12.

3.8.10 Salt spray test.- The valve shall function satisfactorily after exposure to 100 hours of salt spray when tested per 4.6.13.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility - The manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests - The inspection and testing of the shut-off valve shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 A sample of the shut-off valve submitted for qualification tests shall consist of one specimen upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65° and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Qualification tests - The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

A. Examination of product per 4.6.1.

B. Proof pressure per 4.6.2.

C. Pressure drop per 4.6.5.

D. Surge pressure per 4.6.6.

E. Solenoid current drain per 4.6.7.

F. Dielectric strength per 4.6.8.

G. Timing test per 4.6.9.

H. Extreme temperature performance per 4.6.10.

I. Endurance per 4.6.11.

J. Vibration per 4.6.12.

K. Salt spray per 4.6.13.

L. Burst pressure per 4.6.14.

4.4 Acceptance tests - Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

A. Examination of product per 4.6.1.

B. Proof pressure per 4.6.2.

C. Actuation per 4.6.3.

D. Leakage per 4.6.4.

4.5 Test conditions

4.5.1 Test fluid - The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination - Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of particle	Percent by weight of total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	18 ± 3
over 40 micron	9 ± 3

4.5.4 Filtration - The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing - All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity. The test housing shall be acceptable to the procuring agency.

4.5.5.2 Acceptance test housing - The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test methods

4.6.1 Examination of product - Each valve shall be carefully examined to determine conformance with the requirements of this specification for weight, workmanship, marking, conformance of dimensions to applicable drawings, and for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Proof pressure - Pressure shall be applied to the pressure port at a rate not exceeding 25,000 psi per minute until 6000 psi is reached. This proof pressure shall be held for not less than two minutes. The cylinder port shall then be plugged and the solenoid energized. Proof

pressure, 6000 psi, shall be held for at least two minutes. There shall be no external leakage, permanent set, or other damage. For acceptance test the components and the fluid shall be stabilized at a temperature of 95° ± 15 °F and for qualification test the temperature shall be 450° ± 15°F. A hand pump may be used if desired.

4.6.3 Actuation.- The valve shall be cycled 25 times by energizing and de-energizing the solenoid with an 18 volt source of direct current while 4000 psi is applied to the pressure port. Repeat this procedure with a 50 psi differential between the pressure port and the cylinder port. During this test, general functioning of the valve, relation between energized and de-energized position with opening and closing of valve shall be in accordance with paragraph 3.8.4 of this specification. There shall be no external leakage during this test. Flow shall be equal to or greater than rated for the valve to be considered fully open.

4.6.4 Leakage.- Test in accordance with Table I. The valve shall be actuated between each test, and shall be free of air before each measurement. Allow 15 seconds maximum to bring the pressure from zero to test pressure. The measurement period shall begin within 3 minutes after application of test pressure.

TABLE I

LEAKAGE TEST CONDITIONS

Test No.	Test Pressure	Apply Pressure to Port	Valve Position	Measure Time	Max. Allowable Leakage cc/min.
1	4000	Pressure	De-energized	3	6
2	4000	Cylinder	De-energized	3	6

4.6.5 Pressure drop - Determine the pressure drop between the pressure port and the cylinder port at rated flow. A back pressure of 200 psi minimum shall be maintained on the downstream side of the valve. This test shall be run at a fluid temperature of 95° ± 15°F. The pressure drop through the valve shall not exceed 50 psi. This pressure drop does not include the pressure drop through the test manifold or housing.

4.6.6 Surge pressure - The surge pressure test shall be performed at a temperature of 95° ± 15°F. The test shall be set up as shown in Figure 2. With the valve in the de-energized position and the cylinder port open, pressure shall build up to 6000 ± 300 psi in the accumulator. The directional control valve shall then be quickly actuated to permit surge pressure to the pressure port. The test valve shall receive 25 such applications of surge pressure. The total leakage measured at the cylinder port for the 25 surge pressure applications shall not exceed 18cc.

4.6.7 Solenoid current drain - Apply 28 volts direct current to the solenoid. The current drain shall not exceed 1.0 ampere measured 1 second after application of voltage. The ambient temperature shall be 95° ± 15°F for this test. This current shall hold the valve in the open position.

4.6.8 Dielectric strength - The solenoid shall be soaked at not less than 650°F for 8 hours or longer and held at 650°F while 600 volts root mean square is applied between the solenoid and ground for a period of 60 seconds. There shall be no failure or damage to the coils.

4.6.9 Timing test - An oscillograph shall be used to plot electrical input to the solenoid and pressure at the cylinder port, simultaneously. With 4,000 psi applied to the pressure port, energize the solenoid. The time lapse between electrical application and pressure rise to 4,000 + 50 psi at the cylinder port shall not exceed 0.10 second. The temperature shall be 95° ± 15°F for this test.

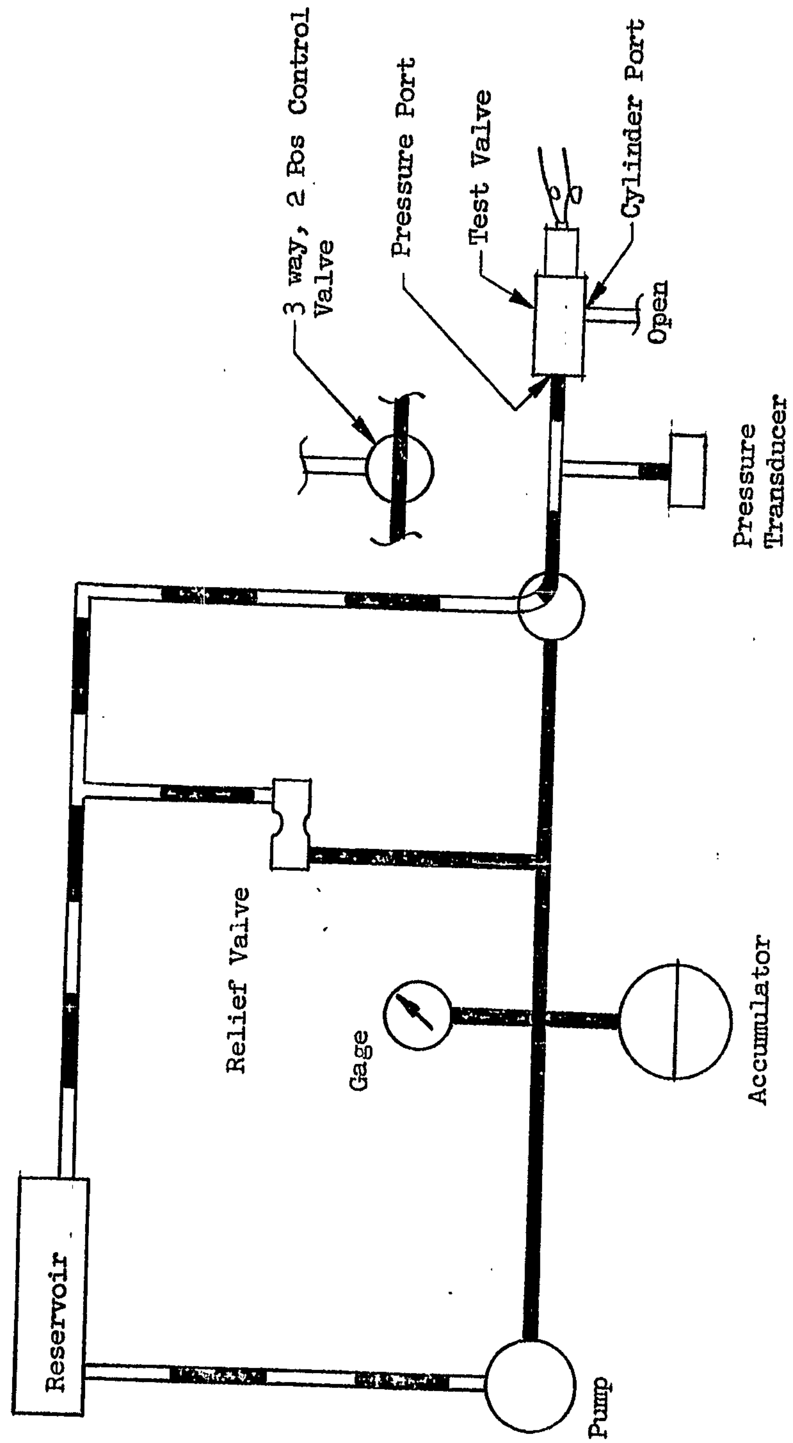


Figure 2

Surge Pressure Test Set Up

4.6.10 Extreme temperature performance

4.6.10.1 Low temperature operation - The test set up shall be similar to Figure 3. Bleed the system of air and charge to 5 to 10 psi. Close valve "A". The test valve shall be maintained at a temperature not warmer than -65°F for 8 hours or longer. The valve shall be de-energized during this soaking period. With 50 psi pressure differential between pressure and cylinder port the valve shall open with no more than 18 volts applied to the solenoid. The valve shall be de-energized and 4000 psi applied to the pressure port. The valve shall open and function properly with no more than 18 volts applied to the solenoid. The voltage shall be decreased and the coil voltage at which the valve will fully close shall be recorded. The temperature shall be raised to -20°F and the above procedure repeated. After this test is completed 6000 psi shall be applied to the pressure port with the temperature held at not warmer than -20°F. Energize the solenoid with 28 volts maximum. The valve shall fully open and function properly. Reduce the voltage slowly until the maximum voltage at which the valve will fully close can be determined. This value shall be recorded. Leakage test shall be performed to 4.6.4 while the valve is not warmer than -20°F.

4.6.10.2 Rapid warm up - The test set-up for the low temperature test shall be used for this test. With valve "A" open and valve "B" closed apply a pressure of 4000 psi to the pressure port of the test valve. The fluid temperature shall be warmed up rapidly from -20°F by closing valve "C" and flowing through the relief valve. When this temperature reaches +74°F valve "C" shall be opened and the solenoid shall be energized

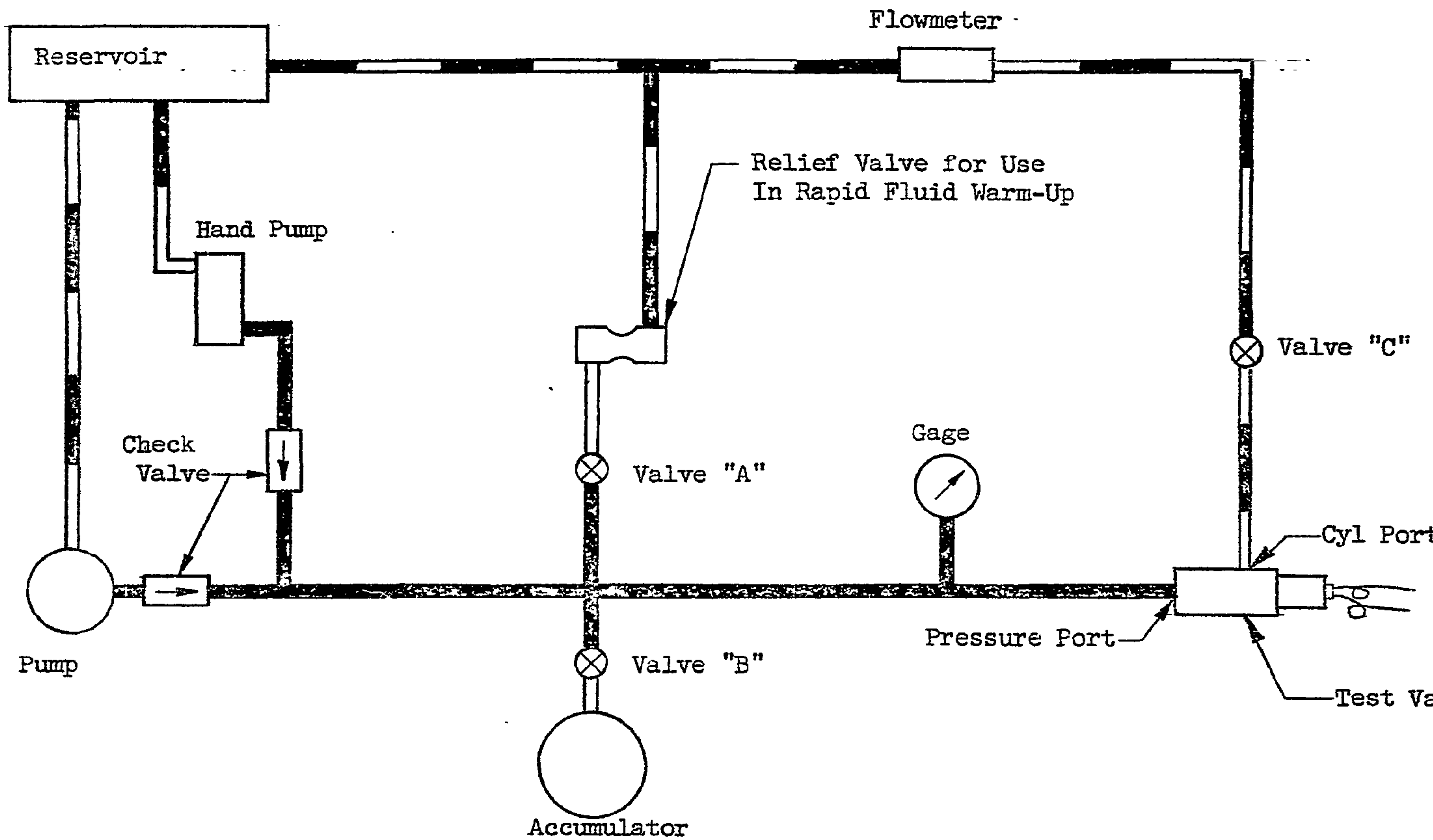


Figure 3

Set Up for Low Temperature and Rapid Warm Up Test

with a maximum of 18 volts for 5 seconds. This shall permit rated flow to pass through the valve. At the end of 5 seconds valve "C" shall be closed and the above procedure repeated when the fluid temperature reaches 168, 262, 356, and 450°F. At each of these checks the test valve shall fully open each time the solenoid is energized and shall fully close each time the solenoid is de-energized.

4.6.10.3 High temperature operation and leakage - The test set-up shall be similar to Figure 4. With the system bled of air and charged to 5 to 10 psi the entire set-up shall be maintained at no less than 450°F for 6 hours or longer. The valve shall be de-energized during this period. Apply 4000 psi pressure to the pressure port and determine the coil voltage required to open the valve. This value shall not exceed 18 volts. Decrease the coil voltage until the valve closes and record this voltage value. Repeat this procedure for five complete cycles. No long waiting period between operations is necessary. Leakage test shall be performed per paragraph 4.6.4 while the valve is at a temperature of 450°F. The allowable leakage rate shall be as specified in Table I. There shall be no external leakage during this test.

4.6.11 Endurance - The test set-up shall be similar to Figure 5. The valve shall be subjected to a total of 20,000 cycles of opening and closing by energizing and de-energizing the solenoid while a pressure of 4000 psi is applied to the pressure port. The valve shall pass maximum rated flow when the valve is in the energized position. The pressure shall be monitored with a transducer and the overshoot pressure shall be recorded.

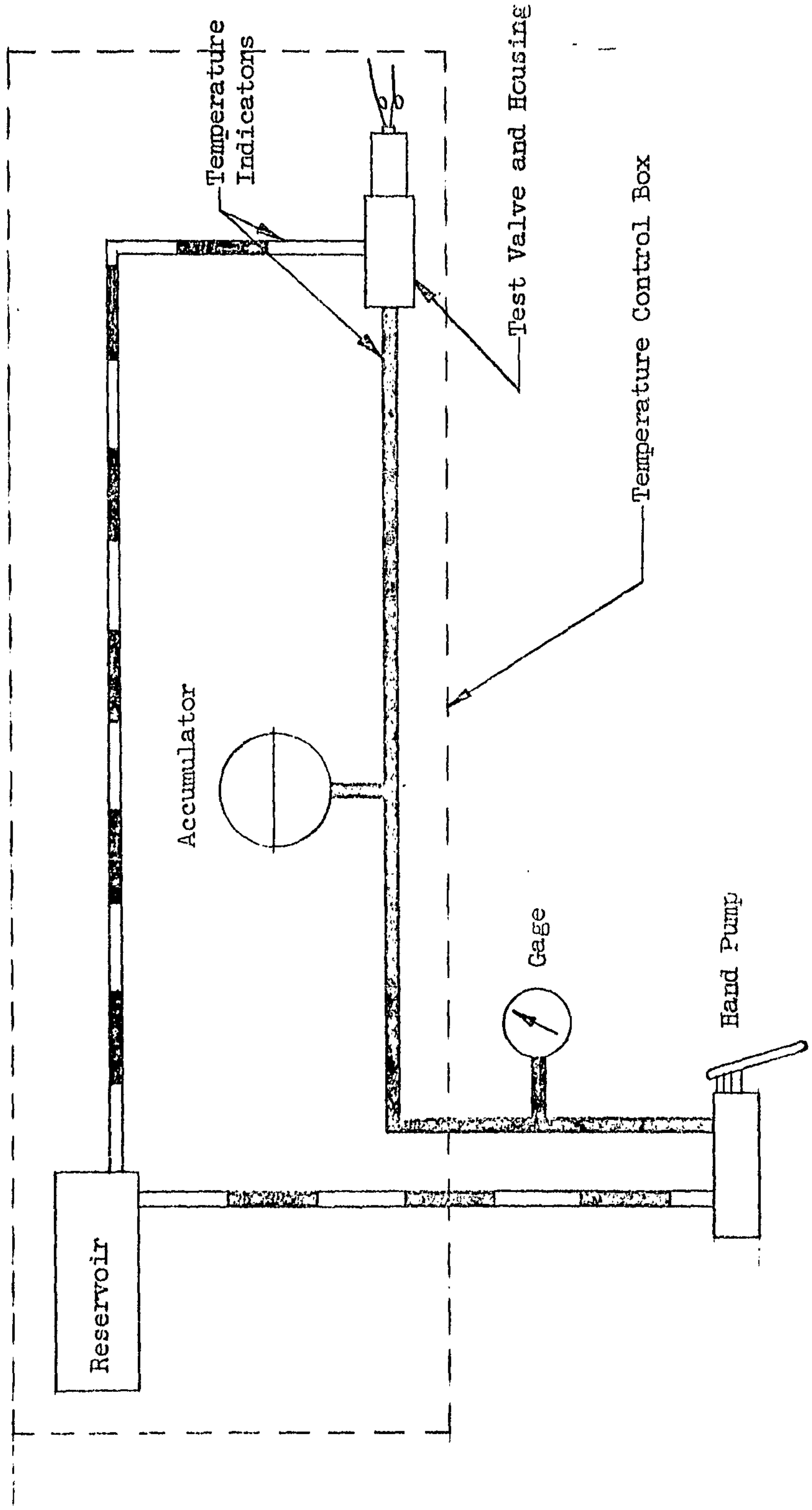


Figure 4

High Temperature Test Set Up

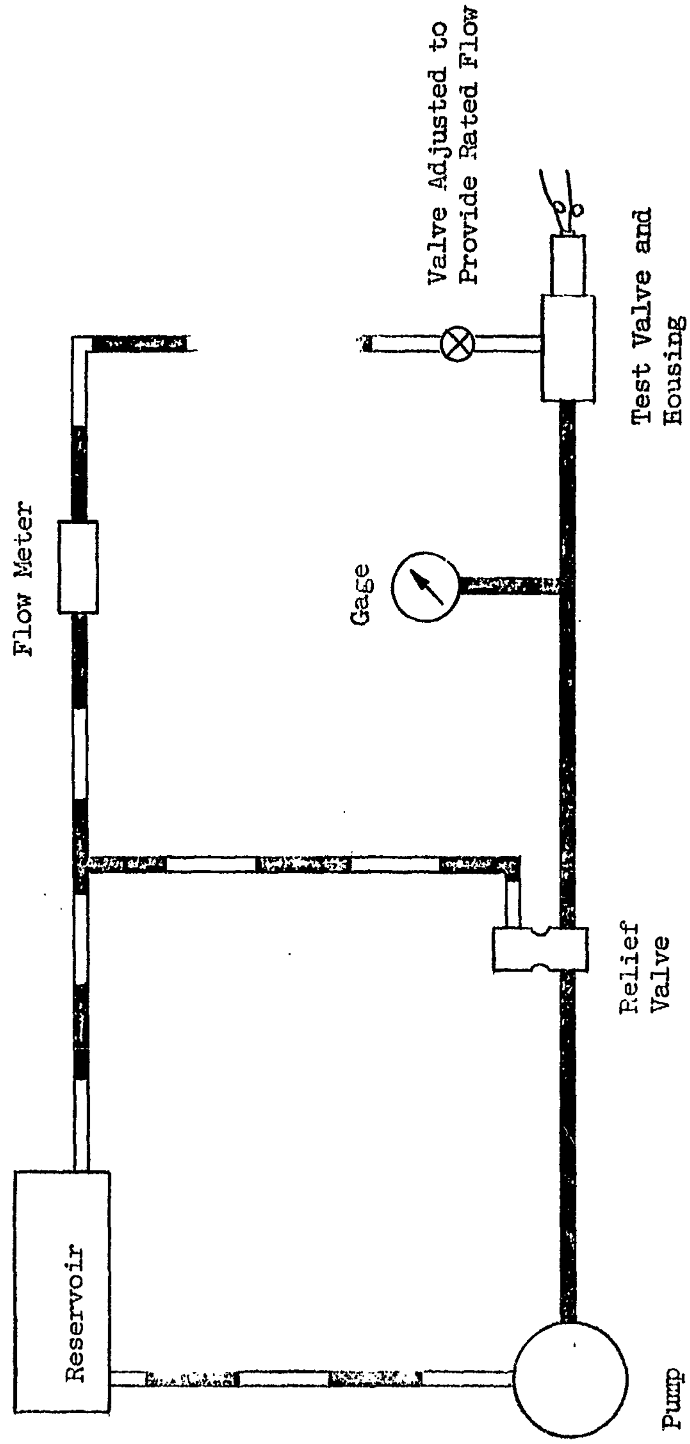


Figure 5

Endurance Test Set Up

The endurance test shall be conducted while the valve undergoes a time-temperature spectrum as shown in Figure 6. The 20,000 cycles shall be accomplished by going through the spectrum four times. The valve shall be cycled at the rate of 12 to 16 cycles per minute. Prior to going through a spectrum, the valve and fluid shall be maintained at a temperature not warmer than -65°F for 8 hours or longer. After completing the four spectrums the valve shall be tested, and shall meet the requirements specified in paragraph 4.6.4. No external leakage shall occur during this test.

4.6.12 Vibration test -

a. With the fluid temperature maintained at 95° ± 15°F the valve shall be actuated at a rate of 12 to 16 cpm. Actuation shall be accomplished by energizing and de-energizing the solenoid while 4000 psi is applied to the pressure port. While the valve is being actuated it shall be vibrated in a horizontal direction with the frequency varying between 5 to 2000 cps in 30 minutes. The amplitude shall be .04 inches (.08 inch total excursion) or 15G whichever is limiting. This test should be repeated two times and during this time the frequency of any and all resonant points (natural frequency) shall be noted. Vibrate the valve for 90 minutes at the most severe resonant frequency noted at .08 inch total excursion or 15G, whichever is less severe. If no resonant frequency is noted the valve shall be vibrated at 500 cps.

b. Repeat (a) changing the direction of vibration 90° horizontally.

c. Repeat (a) changing the direction of vibration to vertical.

NOTES:

1. Rate of temperature rise or decay may vary within the shaded areas shown.

2. Approximately six hours of endurance cycling are to be run in one day.

3. The ambient temperature shall be maintained between 450 - 650°F during the time from the 2nd hour through 5th hour of the spectrum shown.

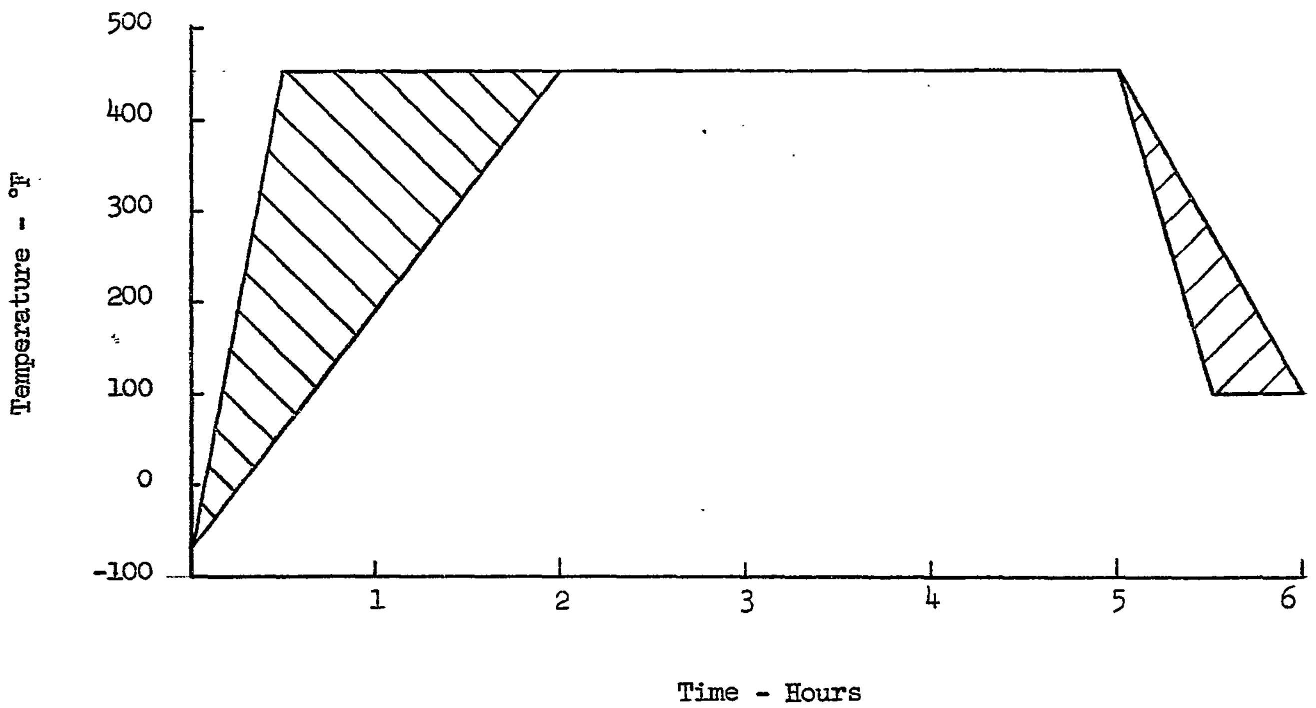


Figure 6

Time - Temperature Spectrum for Endurance Test

d. After completion of (a), (b), and (c) the valve shall be checked per paragraph 4.6.4 except that the allowable leakage given in paragraph 4.6.4 is increased by 50 percent.

e. The valve shall then be removed from the manifold and visually inspected for any mechanical failures.

4.6.13 Salt spray test - The valve shall be installed in the test manifold with electrical connection running outside the test chamber. The valve shall be subjected to a 100 hour salt spray test in accordance with Federal Test Method Standard No. 151, Method 811. At the conclusion of this est period, the valve shall be air dried for 6 hours, then subjected to the Dielectric test (ref. 4.6.8). The valve shall then be cycled by energizing and de-energizing the solenoid with an 18 volt source of direct current with 4000 psi applied to the pressure port. Rated flow shall be passed when the solenoid is energized and no flow must pass when the solenoid is de-energized.

4.6.14 Burst pressure test - With the cylinder port plugged and the valve energized, pressure shall be applied to the pressure port at a rate not to exceed 25,000 psi per minute until 10,000 psi is reached. This pressure shall be held for 2 minutes. There shall be no rupture of external or internal parts. The fluid temperature shall be 95 ± 15°F for this test. This test shall be repeated with the valve de-energized.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging - Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of

components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments.- Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document

Name of part

MS part no.

Month and year of manufacture

Class or size

6. NOTES

6.1 Intended use - The shut-off valve covered by this specification is intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891 and operating with hydraulic fluid conforming to Specification MIL-H-8446. The valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering data - Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number

(c) Class

(d) Federal stock number

6.3 Qualification - With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and the manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

Custodians:

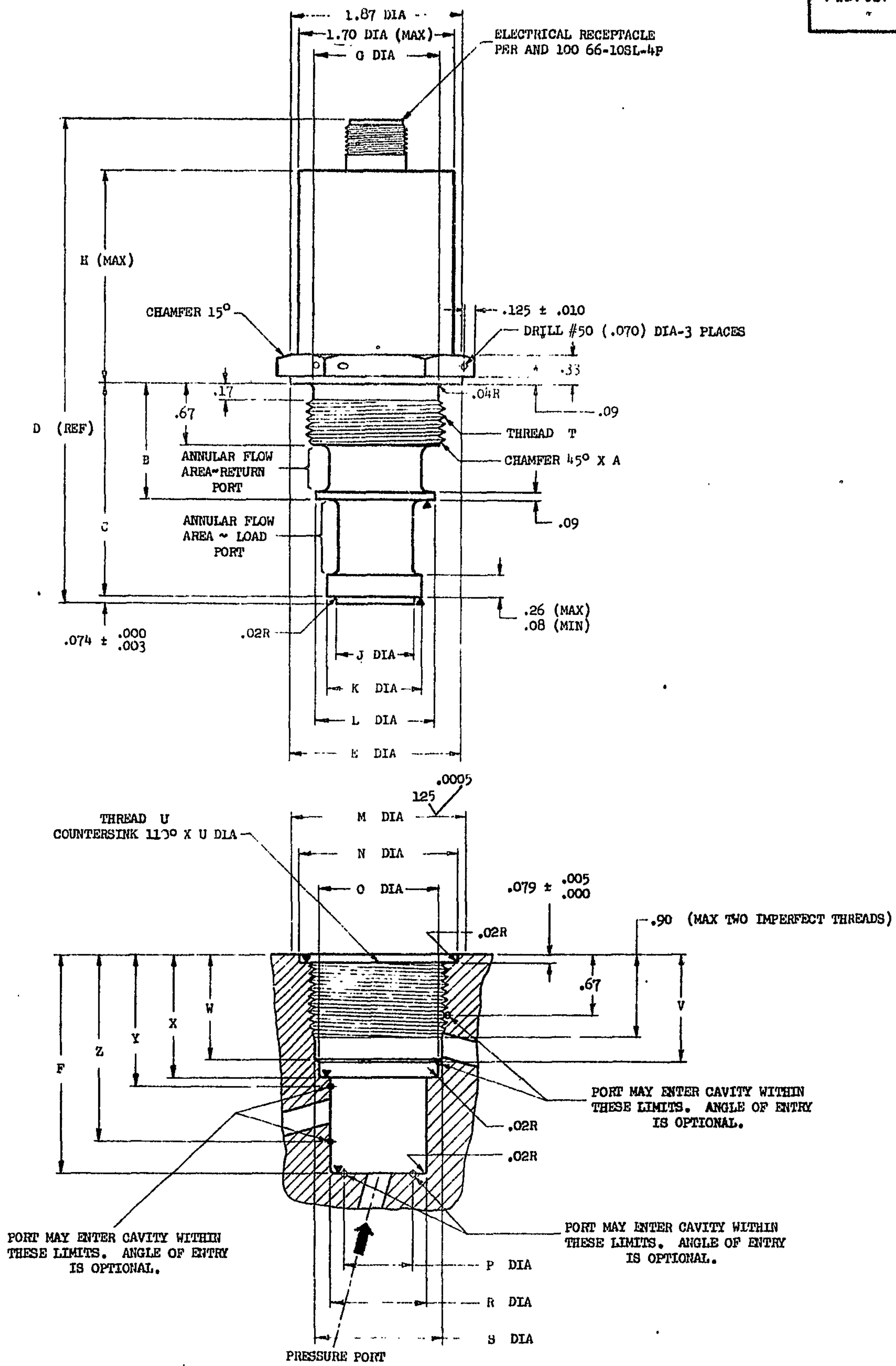
Navy - Bureau of Naval Weapons

Preparing activity:

Navy - Bureau of Naval Weapons

APPENDIX X

Suggested MIL Specification for Solenoid Operated Three-Way, Two Position Selector Valve
Suggested MS Standard for Solenoid Operated Three-Way, Two Position Selector Valve



FED. SUP CLASS

REVISED

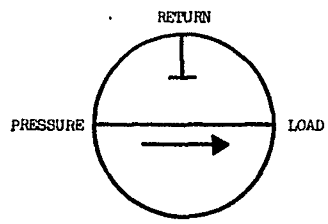
APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE **VALVE, MODULAR HYDRAULIC** **3 WAY, 2 POSITION SELECTOR** 4,000 PSI, TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 2

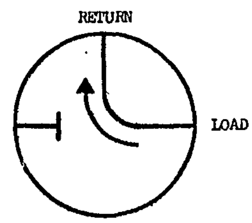
DETAIL REQUIREMENTS

TEMPERATURE LIMITS: +450 FLUID AND +650 AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE: OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI.
FLUID: SPECIFICATION MIL-H-8446.
SEALS: SPECIFICATION MIL-
LIFE: SEE SPECIFICATION MIL- FOR ENDURANCE.
PRESSURE DROP: 50 PSI MAXIMUM AT RATED FLOW.

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▼) SHALL BE 16 RHR. ALL OTHER SURFACES SHALL BE 125 RHR PER MIL-STD-10.
TOLERANCES: THE THREE VALVE SEALING SURFACES SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR. THE SEALING SURFACE DEFINED BY "E" DIAMETER SHALL BE PERPENDICULAR TO THE AXIS OF THE VALVE THREAD WITHIN .001 FIR. THE THREE SEALING SURFACES WITHIN THE CAVITY SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR. THE FACE DEFINED BY "M" DIAMETER SHALL BE PERPENDICULAR TO THE AXIS OF THE CAVITY THREADS WITHIN .001 FIR.
LINEAR TOLERANCE: UNLESS OTHERWISE NOTED ± .01 INCH
ANGULAR TOLERANCE: UNLESS OTHERWISE NOTED ± 2°.
THIS VALVE IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI, TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- . THE ELECTRICAL POWER USED TO ENERGIZE THE VALVE SHALL BE DIRECT CURRENT IN ACCORDANCE WITH SPECIFICATION MIL-E-7894ASG.
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▼ .
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE APPLICABLE MS PART NUMBER, THE WORDS "3 WAY , 2 POSITION SELECTOR VALVE", THE RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON A NAMEPLATE OR DIRECTLY ONTO THE SOLENOID SO THAT THE IDENTIFICATION IS VISIBLE WHEN THE VALVE IS INSTALLED.
THE VALVE IS TO FUNCTION AS SHOWN IN THE FOLLOWING SCHEMATIC.



ENERGIZED



DE-ENERGIZED

VALVE DIMENSIONS

PART NUMBER	THREAD T	A	B +.000 -.003	C +.000 -.003	D (REF)	E DIA	G DIA +.000 -.005	H (MAX)	J DIA	K DIA +.000 -.002	L DIA +.000 -.002	FLOW RATE GPM	WT. (MAX)
MS -1	1 1/2-12UNF-3A	.07	1.250	2.300	5.24	1.88	1.383	2.30	.86	1.057	1.307	4	
MS -2	1 13/16-16N-3A	.05	1.470	2.820	5.96	2.19	1.723	2.50	1.10	1.307	1.557	25	

CAVITY DIMENSIONS

CAVITY FOR PART NUMBER	THREAD U	M DIA	N DIA	O DIA +.002 -.000	P DIA	R DIA +.002 -.000	S DIA	V	W	X +.003 -.000	Y	Z	F +.003 -.000
MS -1	1 1/2-12UNF-3B	1.96	$1.750^{+.002}_{-.000}$	1.312	.80	1.062	$1.4098^{+.0100}_{-.0000}$	1.15	1.12	1.329	1.43	2.04	2.379
MS -2	1 13/16-16N-3B	2.28	$2.062^{+.003}_{-.000}$	1.562	1.04	1.312	$1.7448^{+.0085}_{-.0000}$	1.37	1.34	1.549	1.64	2.56	2.899

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE VALVE, MODULAR HYDRAULIC 3 WAY, 2 POSITION SELECTOR 4,000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 2

MILITARY SPECIFICATION
VALVE: AIRCRAFT HYDRAULIC SELECTOR - SOLENOID OPERATED
3 WAY, 2 POSITION

1. SCOPE

1.1 This specification covers cartridge-type, modular hydraulic, 3 way, 2 position, solenoid-operated, selector valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Selector valves shall be of the following classes:

Class 1 - 0 to 4 GPM
Class 2 - 0 to 25 GPM

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible, Waterproof
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection, Process, Magnetic Particle
MIL-H-6875	Heat Treatment of Steels, (Aircraft Practice) for
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-E-7894	Electrical Power, Aircraft Characteristics of
MIL-H-8891	Hydraulic Systems, Type III; Design, Installation, Tests and Data Requirements, General Specification for
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specifications and Standards, Use of
MS-33540	Safety Wiring - General Practices for
MS-20995	Wire Lock

Federal Test Method Std. No. 151 - Metals; Test Methods

Drawing

MS-

2.2 Other publications - Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification - The selector valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes - Materials and processes used in the manufacture of these valves shall conform to the following requirements and to the applicable specifications as defined in Section 2.

3.2.1 Metals - All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion, during the normal service life of the valve, which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency.

Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel - Close-fitting, sliding, steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts - Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts - Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the manufacturer's drawings.

3.4 Design and construction.

3.4.1 Envelope - The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification and MS-

3.4.2 Hydraulic fluid - The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range - The valves shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F. There shall be no evidence of external leakage or chatter when tested per 4.6.10.

3.4.4 Threads - Only class three threads conforming to specification MIL-S-7742 shall be used.

3.4.5 Seals - Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying - Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety-wire shall be applied in accordance with standard drawings MS-33540 and MS-20995.

3.4.7 Retainer rings - Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valves.

3.4.8 Structural strength - The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight - The weight shall be kept to a minimum consistent with good design, and shall be specified on the applicable drawing.

3.4.10 Mounting position - The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control - The valves shall be designed to pass rated flow per 1.2 from inlet port to outlet when the solenoid is energized. Flow shall be checked or blocked from outlet to inlet port.

3.4.12 Surface roughness - Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.4.13 Solenoid - The solenoid shall be of single coil construction, compact design, and of sufficiently rugged construction to withstand the mechanical shocks and stresses incident to its use in aircraft. Solenoids shall be designed for continuous duty with the solenoid totally enclosed and shall be so designed that the hydraulic fluid can at no time come in contact with the electrical windings. The solenoid shall operate with direct current in accordance with Specification MIL-E-7894.

3.5 Interchangeability

3.5.1 Manufacturer's parts - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability - Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another housing without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification - Each valve shall have the identifying markings placed on the hex-head or the flange so that the identification can be read when the valve is installed in the manifold cavity. Each valve shall be permanently and legibly marked with the following information per MIL-H-7911.

Valve, Selector, 3 Way, 2 position

MS-

Manufacturer's Part Number

Manufactuer's Name or Trademark

3.7 Workmanship

3.7.1 Quality - Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contamination. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection - All magnetizable highly stressed parts shall be subjected to magnetic inspection per Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection per Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated flow and operating pressure - The valves shall be designed to insure satisfactory operation and service life at rated flow per 1.2 and at an operating pressure of 4,000 psi, when tested per 4.6.2. The valves shall be capable of operation at 6,000 psi.

3.8.2 Proof pressure - The valves shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.4. There shall be no external leakage, permanent set, or other damage.

3.8.3 Burst pressure - The valves shall be capable of withstanding a burst pressure of 10,000 psi, when tested per 4.6.13. There shall be no evidence of rupture of internal or external parts.

3.8.4 Valve operation

3.8.4.1 Positions - The valves shall be closed in the de-energized position with the cylinder port open to return and shall be open in the energized position with the pressure port open to the cylinder port, when tested per 4.6.2. Refer to Figure 1.

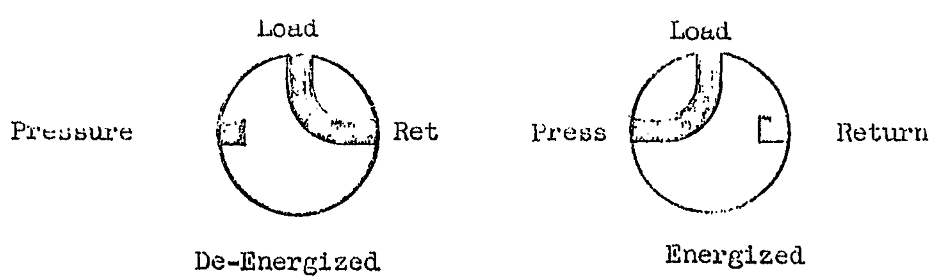


Figure 1

3.8.4.2 Pressures - The valves shall operate with a pressure differential of 50 psi and with pressure on the pressure port in the range from return pressure of 250 psi to 6,000 psi, when tested per 4.6.2.

3.8.4.3 Electrical characteristics -

3.8.4.3.1 The valves shall be designed for a 28 volt direct current system and shall be capable of satisfactory operation when 18 volts is applied at 4,000 psi and when 28 volts is applied at 6,000 psi throughout the ambient and operating temperature ranges, when tested per 4.6.10.

3.8.4.3.2 With 28 volts direct current applied to the coil terminals, the peak current drain shall not exceed 1.0 ampere, when tested per 4.6.7.

3.8.4.3.3 The time lapse between energizing the solenoid and the pressure switch actuation shall not exceed 0.10 second, when tested per 4.6.9.

3.8.4.3.4 There shall be no breakdown of the dielectric material of the solenoid that could cause damage or coil failure when 600 volts rms is applied per 4.6.8.

3.8.5 Internal leakage - The internal leakage of the valves shall not exceed the values of Table I, when tested per 4.6.3.

TABLE I
MAXIMUM ALLOWABLE INTERNAL LEAKAGE

PRESSURE APPLIED psi	PORT PRESSURE APPLIED TO	CLOSED PORTS (Capped)	VALVE POSITION	LEAKAGE PER MINUTE	
				CLASS 1 VALVE	CLASS 2 VALVE
4,000	PRESS.	RETURN	DE-ENERGIZED	10cc	14cc
4,000	PRESS.	CYLINDER	ENERGIZED	10cc	14cc
400	RETURN	CYLINDER	DE-ENERGIZED	2cc	3cc

3.8.6 Pressure drop - The pressure drop through the valves shall not exceed 50 psi when tested per 4.6.5. This pressure drop shall not include the pressure drop through the manifold or housing.

3.8.7 Surge pressure - The valves shall be capable of withstanding a surge pressure of 6,000 psi, when tested per 4.6.6. The internal leakage shall not exceed the values of Table I and valves shall not shuttle.

3.8.8 Endurance - The valves shall be capable of satisfactory operation for a total of 20,000 cycles at a rate of 12 to 16 cpm, when tested per 4.6.11.

3.8.9 Vibration - The valves shall be capable of withstanding vibration from 5 to 2,000 cps at an amplitude of 0.04 inches (0.08 inch total excursion) or 15G whichever is limiting, in each of the three mutually perpendicular planes, when tested per 4.6.12.

3.8.10 Salt spray - The valves shall function satisfactorily after exposure to 100 hours of salt spray, when tested per 4.6.14.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility - The manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests - The inspection and testing of selector valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of selector valves for qualification tests shall consist of one specimen of each class valve upon which qualification .. desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Qualification tests - The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

A. Examination of product per 4.6.1.

B. Proof pressure per 4.6.4.

C. Pressure drop per 4.6.5.

D. Surge pressure per 4.6.6.

E. Dielectric strength per 4.6.8.

F. Solenoid current drain per 4.6.7.

G. Timing test per 4.6.9.

H. Extreme temperature performance per 4.6.10.

I. Endurance per 4.6.11.

J. Vibration per 4.6.12.

K. Salt spray per 4.6.14.

L. Burst pressure per 4.6.13.

4.4 Acceptance tests - Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

A. Examination of product per 4.6.1.

B. Proof pressure per 4.6.4.

C. Actuation per 4.6.2.

D. Leakage per 4.6.3.

4.5 Test conditions

4.5.1 Test fluid - The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature - If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination - Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of particle	Percent by weight of total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	9 ± 3

4.5.4 Filtration - The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing - All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity. The test housing shall be acceptable to the procuring agency.

4.5.5.2 Acceptance test housing - The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test methods.

4.6.1 Examination of product - Each valve shall be carefully examined to determine conformance with the requirements of this specification for weight, workmanship, marking, conformance of dimensions to applicable drawings, and for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ± 5 micro-inches at the level being measured.

4.6.2 Actuation - The valve shall be cycled 25 times by energizing and de-energizing the solenoid with an 18 volt source of direct current while 2000 psi is applied to the pressure port. Repeat this procedure with 4000 psi applied to the pressure port. During this test, general functioning of the valve, relation between energized and de-energized position with opening and closing of valve shall be in accordance with paragraph 3.8.4 of this specification. Actuation and operation shall be acceptable at 18 volts direct current. There shall be no external leakage during this test. Repeat the above test with 6000 psi applied

to the pressure port.

4.6.3 Leakage - Test in accordance with Table II. The valve shall be actuated between each test, and shall be free of air before each measurement. Allow 15 seconds maximum to bring the pressure from zero to test pressure. The measurement period must begin within 3 minutes after application of test pressure.

TABLE II
LEAKAGE TEST CONDITIONS

Class Valve	Test No.	Test Pressure	Apply Pressure to Port	Ports Capped	Valve Position	Measure Time	Allowable Leakage/ Minute (max)
1	1	4,000	Pressure	Return	De-energized	3 min.	10 cc
1	2	4,000	Pressure	Cylinder	Energized	3 min.	10 cc
1	3	400	Return	Cylinder	De-energized	3 min.	2 cc
2	1	4,000	Pressure	Return	De-energized	3 min.	14 cc
2	2	4,000	Pressure	Cylinder	Energize	3 min.	14 cc
2	3	400	Return	Cylinder	De-energized	3 min.	3 cc

4.6.4 Proof pressure - This test shall be performed at a stabilized temperature of $450^{\circ} \pm 15^{\circ}$F. Pressure shall be applied to the pressure port at a rate not exceeding 25,000 psi per minute until 6000 psi is reached. This proof pressure shall be held for at least two minutes. The cylinder port shall then be plugged and the solenoid energized. With the valve spool in this position, a proof pressure of 6000 psi shall be held for at least two minutes. There shall be no external leakage, permanent set, or other damage. The temperature for acceptance testing shall be $95^{\circ} \pm 15^{\circ}$F. A hand pump may be used if desired.

4.6.5 Pressure drop - For the rated flow for each class valve, determine the pressure drop between the pressure port and cylinder port and between the cylinder port and the return port. A back pressure of 200 psi, minimum shall be maintained on the downstream side of the valve. This test shall be run at a fluid temperature of $95^{\circ} \pm 15^{\circ}$F and the pressure drop through the valve shall not exceed 50 psi. The pressure drop will not include the pressure drop through the test manifold or housing.

4.6.6 Surge pressure - The surge pressure test shall be performed at a temperature of $95^{\circ} \pm 15^{\circ}$F. The test shall be set up as shown in Figure 2. The cylinder port and the return port shall be open and the test valve shall be in the de-energized position. The directional control valve shall allow pressure to build-up to 6000 psi in the accumulator with the test valve pressure port vented to return. The directional control valve shall be quickly actuated to permit surge pressure to the pressure port. The test valve shall receive 25 such applications of surge pressure within a period of 2 minutes. The valve shall not shuttle or show signs of leakage exceeding the values given in Table II.

4.6.7 Solenoid current drain - Apply 28 volts direct current to solenoid. The current drain shall not exceed 1.0 ampere at $95^{\circ} \pm 15^{\circ}$F 1.0 second after energizing solenoid.

4.6.8 Dielectric strength - The solenoid shall be soaked at not less than 650°F for 8 hours or longer and held at 650°F while 600 volts root mean square is applied between the solenoid and ground for a period of 60 seconds. There shall be no failure or evidence of damage to insulation.

4.6.9 Timing test - An oscillograph shall be used to plot electrical input to the solenoid and pressure at the cylinder port, simultaneously. With the return port open to drain, cap the cylinder port with a pressure switch adjusted to actuate at 3000 psi. Energize the solenoid. The pressure switch shall

actuate in 0.10 second maximum. De-energize the solenoid. Within 0.10 seconds the pressure switch shall actuate. The inlet pressure shall be 4000 psi and the temperature 95° ± 15°F for this test.

4.6.10 Extreme temperature performance -

4.6.10.1 Low temperature operation - The test set up shall be similar to Figure 3. Bleed the system of air and charge to from 5 to 10 psi. Close valve "A" and "C". The test valve shall be maintained at a temperature not warmer than -65°F for 8 hours or longer. The valve shall be de-energized during this soaking period. A differential pressure between pressure port and cylinder port of 250 psi shall be maintained across the valve. A maximum of 18 volts shall be required to open the valve and pass rated flow. The solenoid shall be de-energized and 4000 psi applied to the pressure port. The voltage to the solenoid shall be increased and the coil voltage that will fully open the valve shall be 18 volts max. The solenoid voltage shall be decreased and coil voltage at which the valve fully closes shall be recorded. The temperature shall then be raised to -20°F and the above procedure repeated. After completion of the above procedure and with the temperature held not warmer than -20°F the pressure shall be increased to 6000 psi. The voltage required to fully open the valve shall then be determined and this value shall be 28 volts maximum. Decrease the solenoid voltage and determine the coil voltage at which the valve will fully close.

4.6.10.2 Rapid warm up - The test set up in the low temperature test shall be warmed up rapidly from -20°F. Apply 4000 psi hydraulic pressure to the pressure port. Valve "A" shall be open and valve "B" shall be closed. Valve "C" shall be

adjusted to obtain rated flow at $95^{\circ} \pm 15^{\circ}F$. Fluid external to the cold box shall be stabilized before test at $95^{\circ}F \pm 15^{\circ}F$ reservoir fluid temperature. The voltage required to fully open and the voltage at which the valve will return to the closed position shall be measured in approximately six equal increments while the valve warms up to $450^{\circ}F \pm 15^{\circ}F$. The voltage at which the valve will fully open shall be 18 volts maximum for all temperatures. No external leakage shall occur during this test.

4.6.10.3 High temperature operation and leakage - The test set-up shall be similar to Figure 4. With the system bled of air and pressurized with fluid at 4000 psi, the entire set-up shall be maintained at $450^{\circ}F$ minimum temperature for not less than 6 hours. The valve shall be de-energized during this period. Determine the coil voltage required to fully open the valve. This value shall not be greather than 18 volts. Decrease the coil voltage and determine the voltage at which the valve will fully close. Repeat this procedure for five complete cycles. The pressure shall be maintained at 4000 psi on the pressure port during this test. No long waiting period between operations is necessary. Leakage test shall be performed per paragraph 4.6.3 while the valve is at a temperature of $450^{\circ}F$. The internal leakage rate shall not be greater than the values given in Table II. There shall be no external leakage during this test. With a differential pressure of 250 psi across the valve, determine the voltage required to open the valve and pass rated flow.

4.6.11 Endurance - The test set-up shall be similar to Figure 5. The valve shall be subjected to a total of 20,000 cycles of opening and closing by energizing and de-energizing the solenoid while a pressure 4000 psi is applied to the pressure port and the valve passes maximum rated flow. The endurance test shall be conducted while the valve undergoes a time-temperature spectrum

as shown in Figure 5. The 20,000 cycles shall be accomplished by going through the spectrum four times. The valve shall be cycled at the rate of 12 to 16 cycles per minute. Prior to going through a spectrum, the valve and fluid shall be soaked at a temperature not warmer than -65°F minimum for 8 hours or longer. After completing the four spectrums the valve shall be tested and shall meet the requirements as specified in paragraph 4.6.3. No external leakage shall occur during this test.

4.6.12 Vibration test -

a. With the fluid temperature maintained at 95° ± 15°F the valve shall be cycled at a rate of 12 to 16 cpm. Cycling shall be accomplished by energizing and de-energizing solenoid while 4000 psi pressure is applied to pressure port. While the valve is being cycled it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2000 cps in 30 minutes. The amplitude shall be .04 inches (.08 inch total excursion) or 15G whichever is limiting. This test shall be repeated two times and during this time the frequency of any and all resonant points shall be noted. Vibrate the valve for 90 minutes at the most severe resonant frequency noted above at .08 in total excursion or 15 G, whichever is less severe. If no resonant frequency is noted the valve shall be vibrated at 500 cps.

b. Repeat (a) changing the direction of vibration 90° horizontally.

c. Repeat (a) changing the direction of vibration to vertical.

d. After completion of (a), (b) and (c) the valve shall be checked per paragraph 4.6.3 except that the allowable leakage shall be increased by 50 percent.

e. The valve shall then be removed from the manifold and visually inspected for any mechanical failures.

4.6.13 Burst pressure test - With the cylinder port plugged and the solenoid energized, pressure shall be applied to the inlet port at a rate not to exceed 25,000 psi per minute until 10,000 psi is reached. This pressure shall be held for 2 minutes. There shall be no rupture of external or internal parts. The fluid temperature shall be 450 ± 15°F for this test. With the cylinder port still plugged, the solenoid de-energized, and 10,000 psi applied to the pressure port, pressure shall be applied to the return port at a rate not to exceed 25,000 psi/min. until 5,000 psi is reached. There shall be no evidence of rupture of external or internal parts.

4.6.14 Salt spray test - The valve shall be subjected to a 100 hour salt spray test in accordance with Federal Test Method Standard No. 151, Method 811. At the conclusion of this test period, the solenoid shall be air dried for 6 hours, then subjected to a Dielectric test at 60 cps with 600 volts, root mean square, for 60 seconds. With 4000 psi applied to the pressure port the valve shall then be energized with no more than 18 volts and the valve shall open and pass rated flow.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging - Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in

accordance with the manufacturer's commercial practices.

5.2 Marking of shipments - Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document

Name of part

MS part No.

Month and year of manufacture

Class or size

6. NOTES

6.1 Intended use - The selector valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891 and operating with hydraulic fluid conforming to Specification MIL-H-8446. The valve is further intended for use in a manifold or packaged type system.

6.2 Ordering data - Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number

(c) Class

(d) Federal stock number

(e) Pressure setting

6.3 Qualification - With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that

date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

Preparing activity:

Navy - Bureau of Naval Weapons

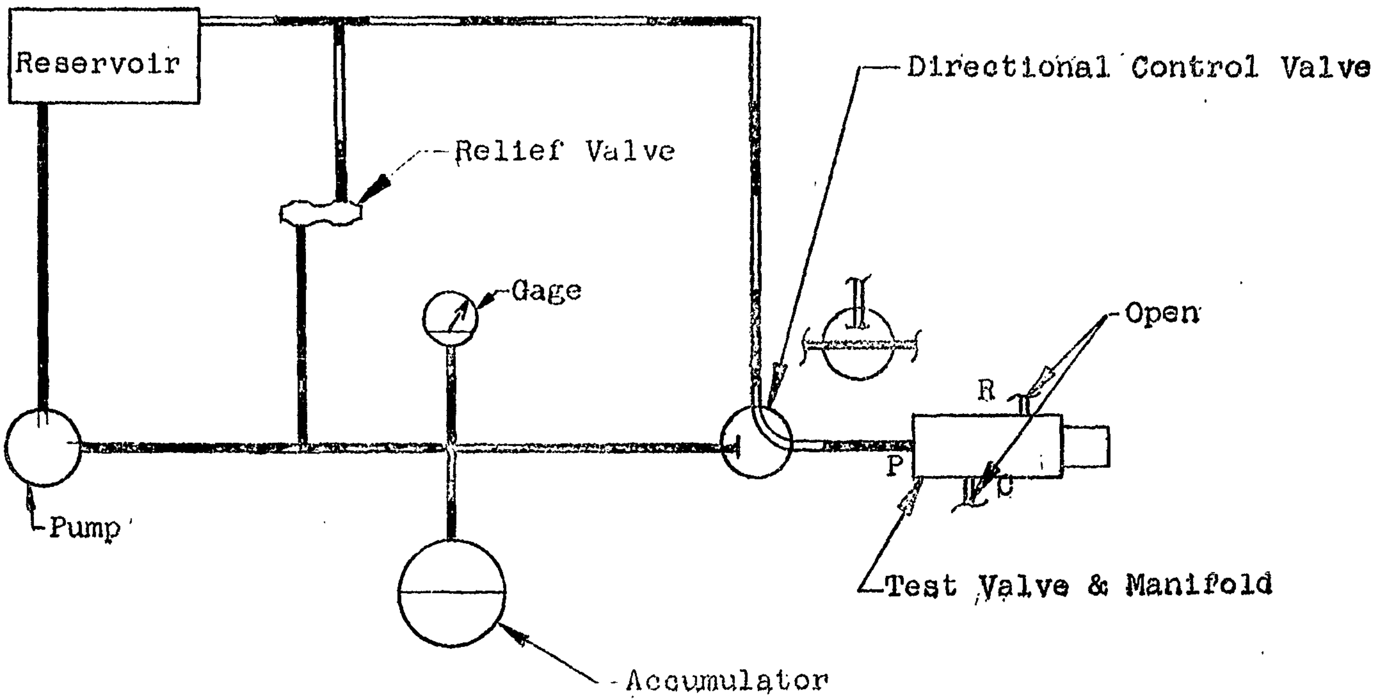


Figure 2 - Surge Pressure Test Set-Up

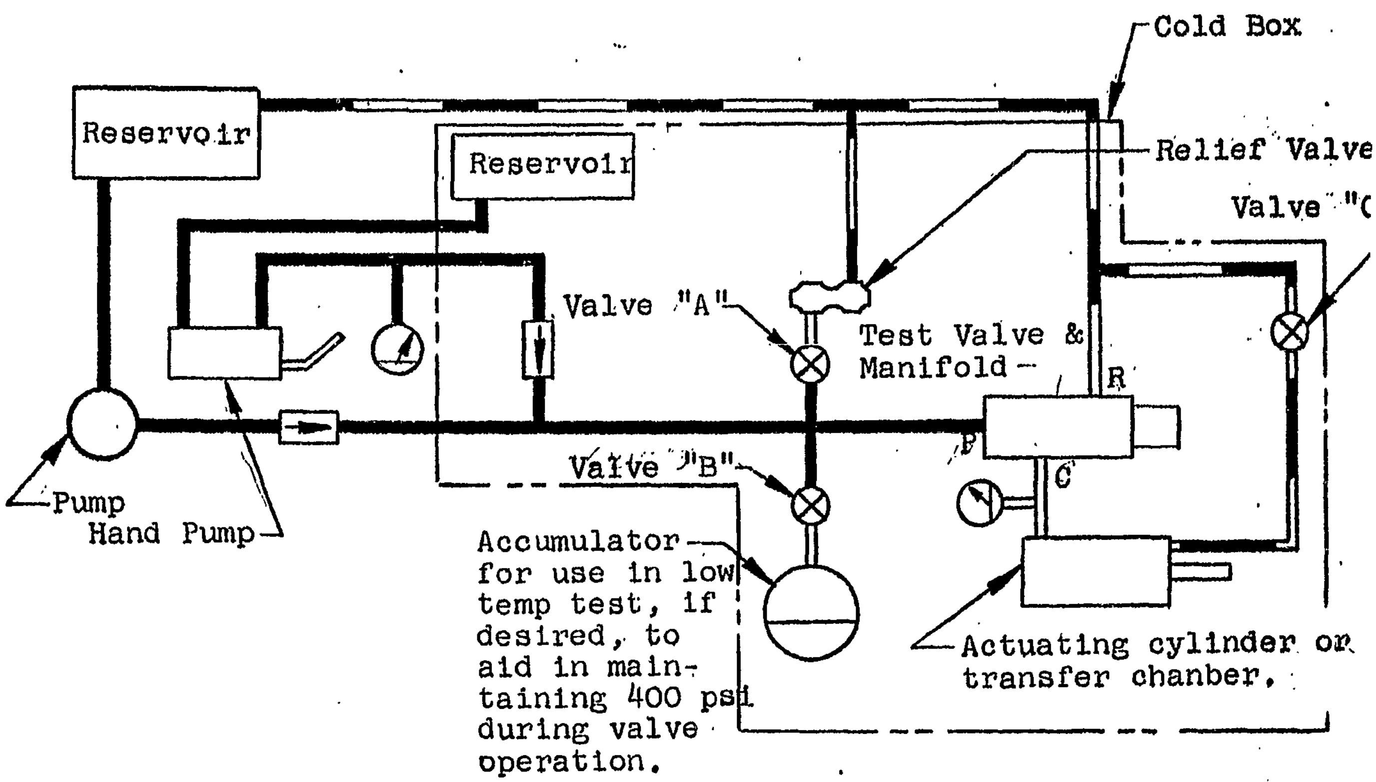


Figure 3 - Low Temperature & Rapid Fluid Warm-Up Test Set-Up

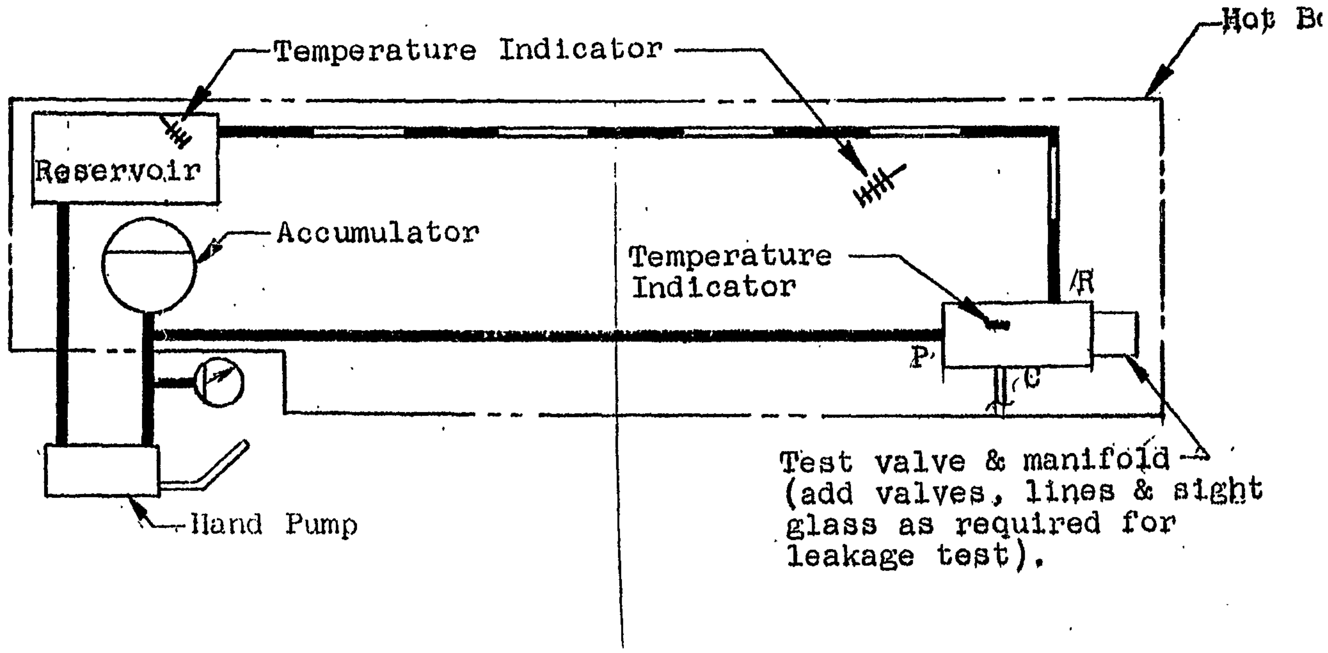


Figure 4 - High Temperature Test Set-Up

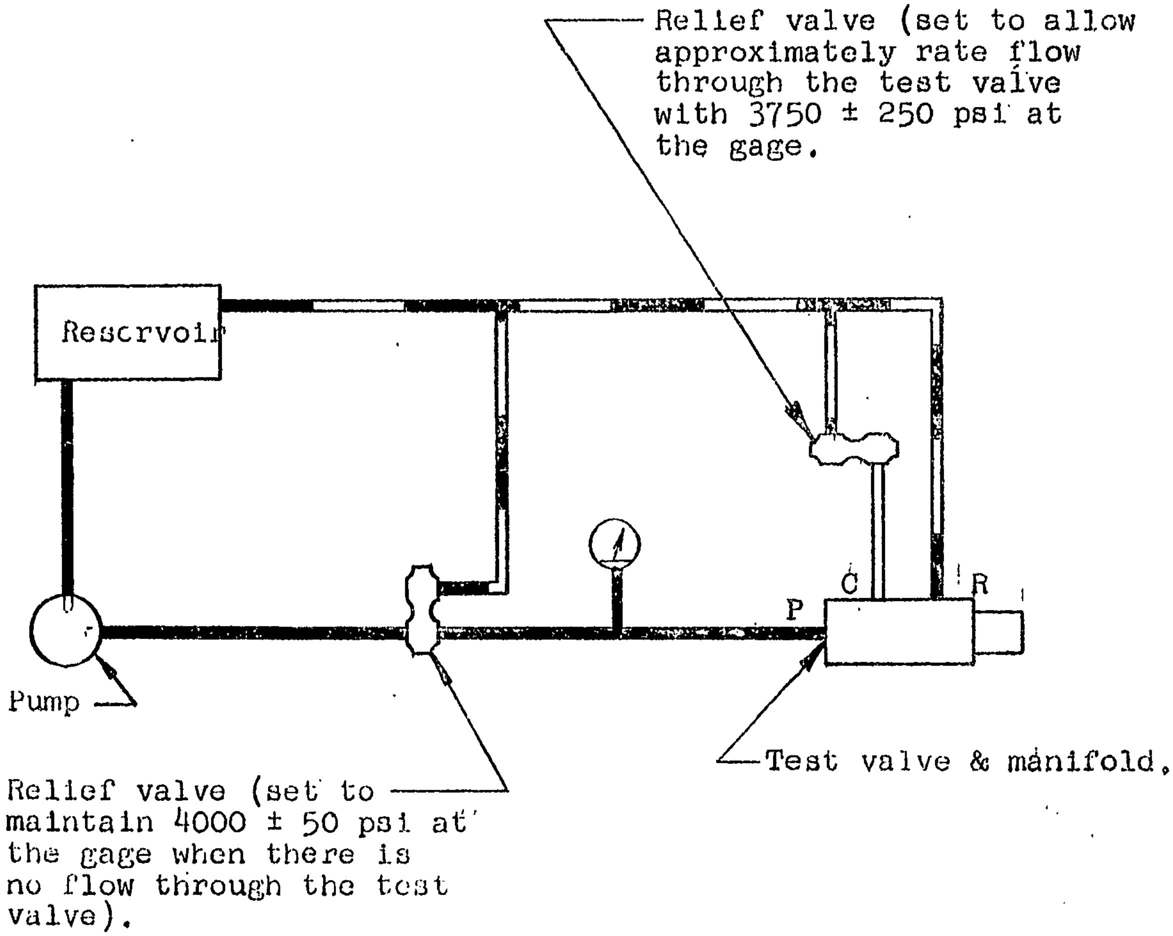


Figure 5 - Endurance Test Set-Up

Notes:

1. Rate of temperature rise or decay may vary within the shaded areas shown.

2. Approximately six hours of encurance cycling are to be run in one day.

3. Ambient temperature shall be maintained at 650°F during the time from the 2nd hour through the 5th hour of the spectrum shown.

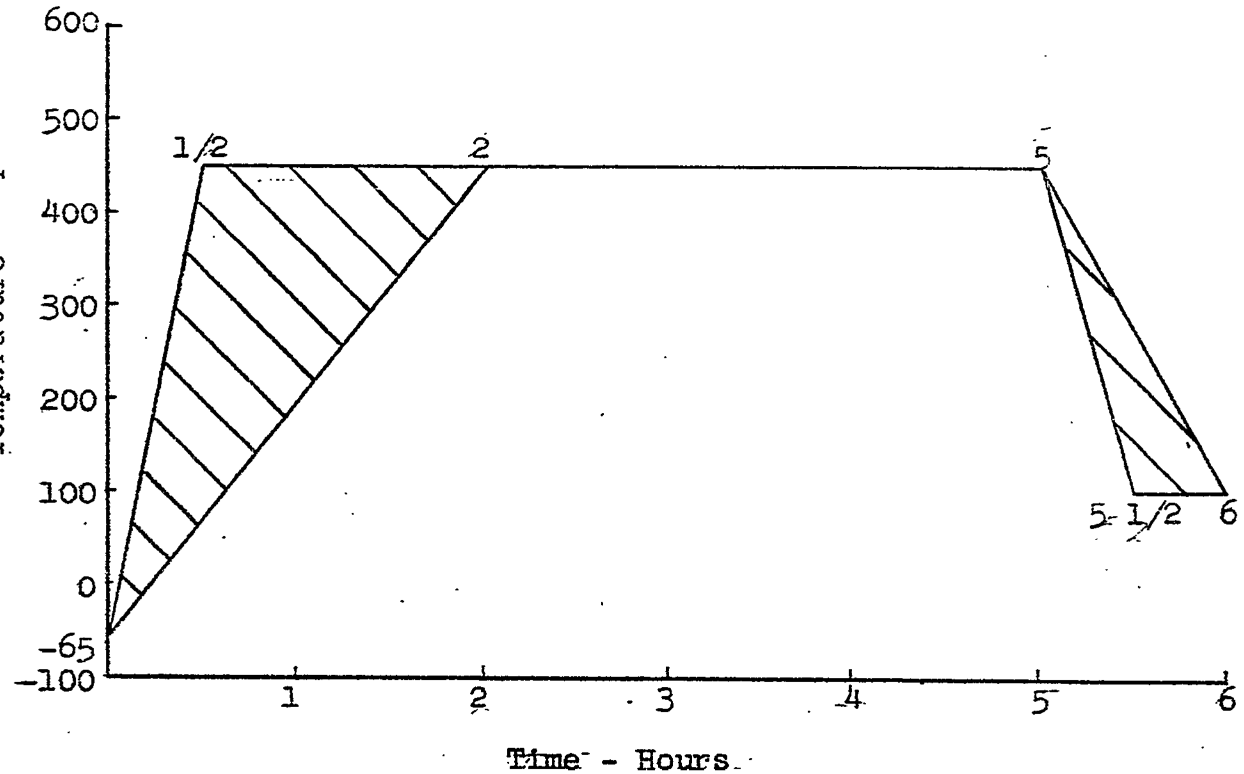


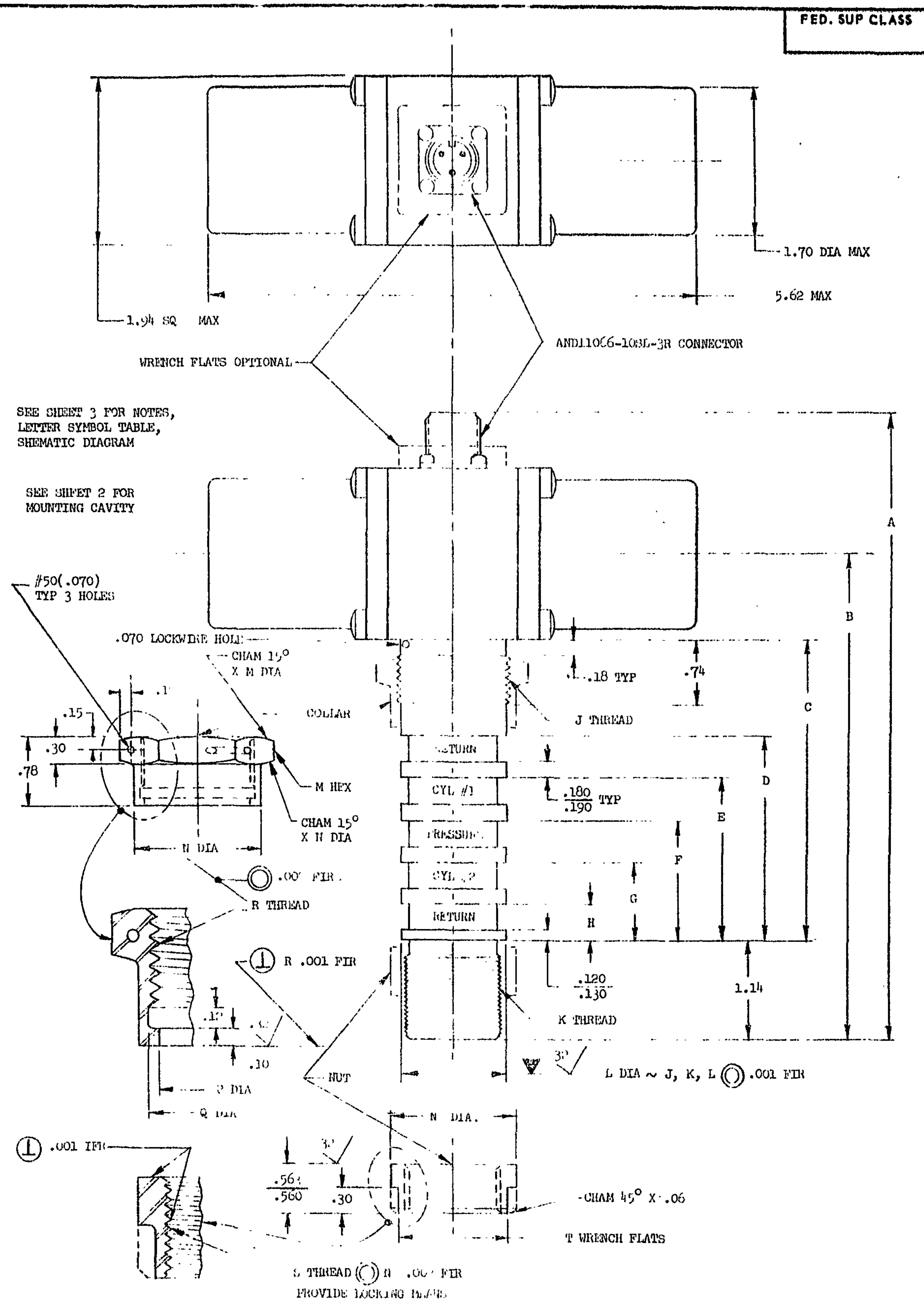
Figure 6

APPENDIX XI

Suggested MIL Specification for Solenoid Operated Four-Way
Three-Position Selector Valve
Suggested MS Standard for Solenoid Operated Four-Way
Three-Position Selector Valve
(Cartridge Type)

Suggested MS Standard for Solenoid Operated Four-Way
Three-Position Selector Valve
(Face Mounted Type)

FED. SUP CLASS



REVISED

APPROVED

P.A. Other Cust	TITLE **VALVE, MODULAR** **HYDRAULIC 4 WAY 3 POSITION SOLENOID** 4000 PSI TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 1 OF 3

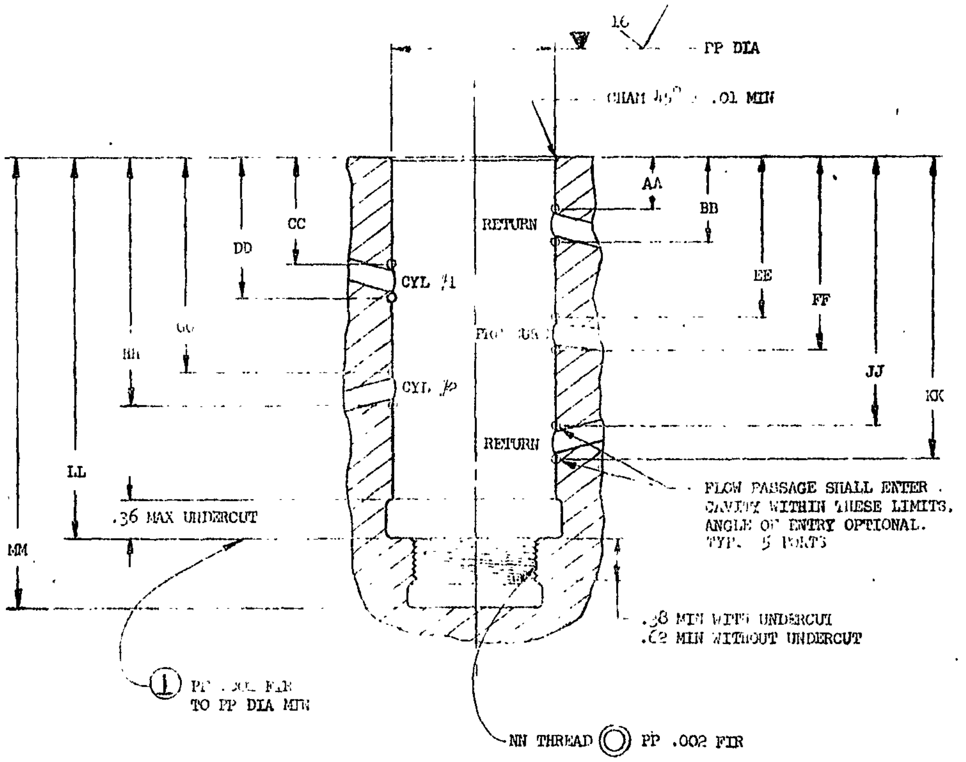
VALVE DIMENSIONS

PART NUMBER	A MAX	B MAX	C	D .000 -.010	E	F	G	H	J UN-3A THD	K NEF-3A THD
MS -1	7.16	5.55	4.55	2.345	1.869	1.379	.899	.419	1 5/16-12	1 1/8-18
MS -2	8.12	6.56	5.54	3.340	2.670	1.980	1.300	.620	1 7/16-12	1 3/16-18
MS -3	[illegible]	7.79	6.77	4.550	3.640	2.730	1.800	.870	1 3/4-12	1 1/2-18

PART NUMBER	L .000 -.001	[illegible] .00[illegible] -.019	N .000 -.005	[illegible] .0100 -.0000	[illegible] .003 -.000	R UN-3B THD	S NEF-3B THD	T .002 -.010	FLOW GPM	MAX WT LBS
MS -1	1.212	1.500	1.455	1.2223	1.336	1 5/16-12	1 1/8-18	1.250	4	4.5
MS -2	1.337	1.625	1.575	1.3473	1.461	1 7/16-12	1 3/16-18	1.313	12	4.5
MS -3	1.649	2.000	1.885	1.6598	1.774	1 3/4-12	1 1/2-18	1.625	25	4.5

CAVITY DIMENSIONS

	AA	BB	CC	DD	EE	FF	GG	HH	JJ	KK	LL	MM	NN	PP
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	.003 -.000	MIN	NEF-3B THREAD	.001 -.000
MS -1	.484	.746	.965	1.231	1.439	1.723	1.915	[illegible]	2.398	2.696	3.395	4.02	1 1/5-18	1.460
MS -2	.450	.898	1.126	1.588	1.800	2.260	2.483	[illegible]	3.167	3.647	4.353	4.97	1 3/16-18	1.585
MS -3	.406	1.062	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.102	4.758	5.497	6.12	1 1/2-18	1.898



SEE SHEET 3 FOR NOTES.

PORTING & SEALING CAVITY

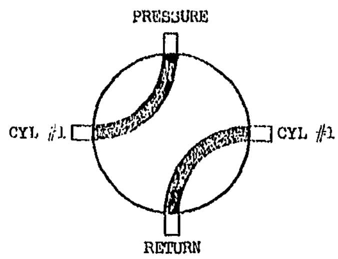
FED. SUP CLASS

REVISED

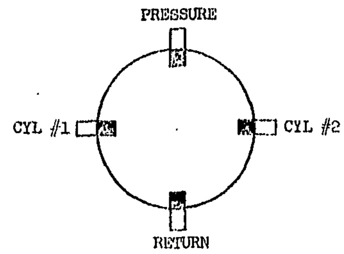
APPROVED

P.A. Other Cust	TITLE **VALVE, MODULAR** HYDRAULIC 4 WAY 3 POSITION SOLENOID 4000 PSI TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 2 OF 3

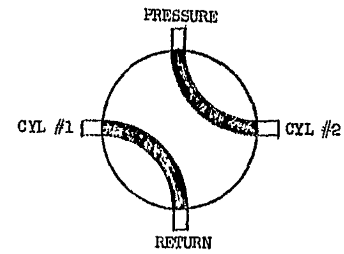
FED. SUP CLASS



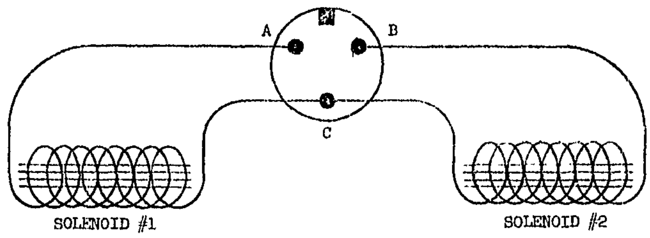
SOLENOID #1 ENERGIZED



BOTH SOLENOIDS DE-ENERGIZED



SOLENOID #2 ENERGIZED



SCHEMATIC WIRING & FLOW DIAGRAMS

DETAIL REQUIREMENTS

TEMPERATURE LIMITS	-	450°F FLUID AND 650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65 °F.
PRESSURE	-	OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI
FLUID	-	SPECIFICATION MIL-H-8446
SEALS & SPACERS	-	MS
LIFE	-	SEE SPECIFICATION MIL- FOR ENDURANCE
PRESSURE DROP	-	50 PSI MAXIMUM AT RATED FLOW

MATERIAL: SEE PROCUREMENT SPECIFICATION
FINISH: SEE PROCUREMENT SPECIFICATION
MACHINE FINISH: 125/ UNLESS OTHERWISE SPECIFIED.
TOLERANCES: UNLESS OTHERWISE SPECIFIED: LINEAR ±.01, ANGULAR ±30'.
SEALING SURFACES DENOTED BY SYMBOL ▲.
SYMBOLS: FOR CONCENTRICITY, FOR SQUARENESS, NON-SPECIFIED CONCENTRICITIES ON SAME MUTUAL ℄ TO .020 FIR.
THREADS: MIL-S-7742. CHAMFER ENDS OF THREADS 38° ± 7° X ROOT DIAMETER MINIMUM TO ROOT DIAMETER +.03.
THE APPLICABLE MS PART NUMBER, THE WORDS "4 WAY, 3 POSITION VALVE", AND THE MANUFACTURER'S NAME OR TRADE-MARK SHALL BE PERMANENTLY MARKED SO THAT THE IDENTIFICATION IS VISIBLE WHEN THE VALVE IS INSTALLED.

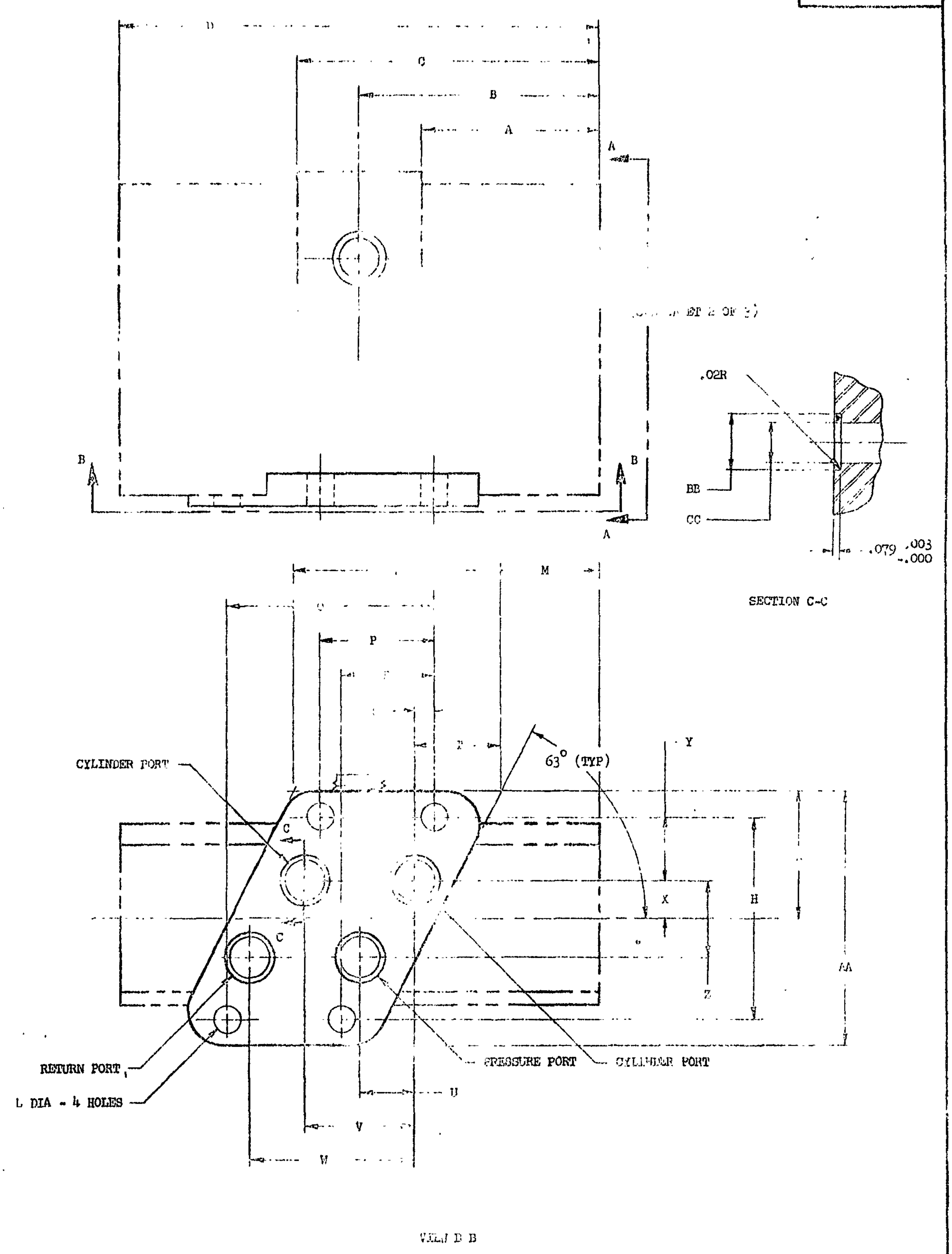
TORQUE = 100 FT POUND ON COLLAR TO EFFECT A SEAL WITH MS SEALS.
APPLY THREAD LUBRICANT TO THREAD J.
CAN NOT BOTTOM OUT VALVE IN CAVITY -- MUST BE BACKED OFF BEFORE TORQUEING COLLAR TO SPECIFIED VALUE.
CAVITY WALL THICKNESS IN AREA OF MS SEALS SHALL NOT BE LESS THAN 0.12 FOR CLASS A VALVE, 0.18 FOR THE CLASS B VALVE, OR 0.23 INCH FOR THE CLASS C VALVE.

REVISED

APPROVED

P.A. Other Cust	TITLE **VALVE, MODULAR** **HYDRAULIC 4 WAY 3 POSITION SOLENOID** 4000 PSI TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 3 OF 3

FED SUP CLASS

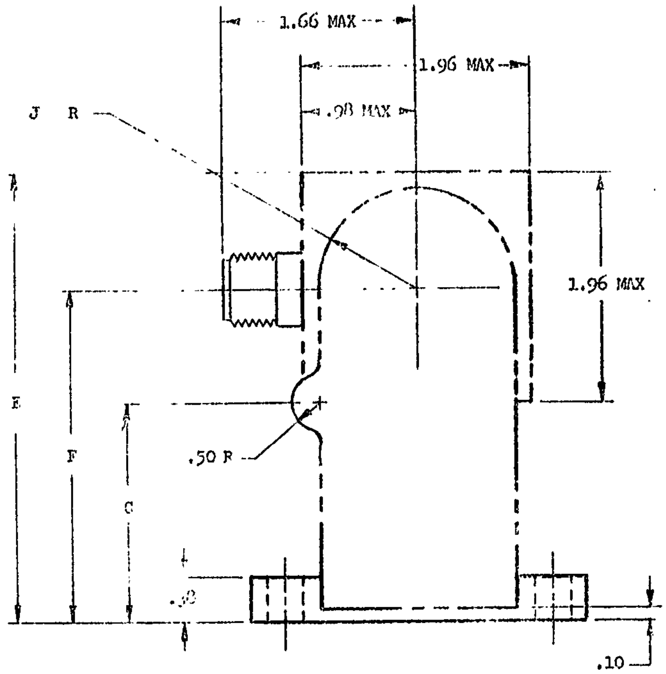


REVISED

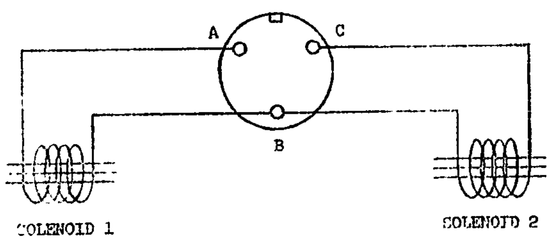
APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE VALVE, MODULAR HYDRAULIC 4 WAY [illegible] POSITION SELECTOR (FACE MOUNTED) 4000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 1 OF 3

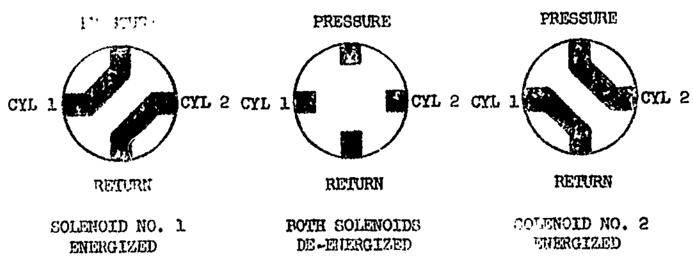
FED. SUP CLASS



VIEW A-A



WIRING DIAGRAM



SCHEMATIC DIAGRAM

REVISED

APPROVED

P.A. NAVY BUWEPS Other Cust	TITLE VALVE, MODULAR HYDRAULIC 4 WAY, 3 POSITION SELECTOR (FACE MOUNTED) 4000 PSI, TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION MIL-	SUPERSEDES:	SHEET 2 OF 3

FED. SUP CLASS

PART NUMBER	FLOW RATE	A MAX	B MAX	C MAX	D MAX	E MAX	F MAX	G MAX	H	J RAD MAX	K	L	M MAX
MS -1	4 GPM	2.07	2.79	3.51	5.58	3.48	2.50	1.36	1.98	.85	1.25	.272	1.56
MS -2	12 GPM	2.07	2.79	3.51	5.58	3.82	2.84	1.56	2.32	.85	1.46	.339	1.15
MS -3	25 GPM	2.78	3.50	4.22	7.00	4.08	3.10	1.74	2.86	.98	1.80	.413	1.78

PART NUMBER	N	O	P	R	S	T	U	V	W	X	Y	Z	AA	BB +.001 -.000	CC MAX	MAX WT
MS -1	1.58	1.70	.80	.90	.25	.82	.40	.80	1.20	.40	.59	.80	2.50	.468	.283	
MS -2	2.42	2.42	1.32	1.08	.22	1.00	.64	1.28	1.92	.44	.72	.88	2.92	.656	.471	
MS -3	3.42	3.22	1.78	1.44	.24	1.26	.96	1.76	2.72	.54	.93	1.08	3.60	.875	.690	

DETAIL REQUIREMENTS

TEMPERATURE LIMITS - +450°F FLUID AND +650°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -65°F.
PRESSURE - OPERATING 4,000 PSI, PROOF 6,000 PSI, BURST 10,000 PSI.
FLUID - SPECIFICATION MIL-H-8446.
SEALS - SPECIFICATION MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE.
PRESSURE DROP - 75 PSI MAXIMUM AT RATED FLOW

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SURFACES SHALL BE 125 RHR PER MIL-STD-10 UNLESS OTHERWISE NOTED.
LINEAR TOLERANCE: UNLESS OTHERWISE NOTED ±.01 INCH.
ANGULAR TOLERANCE: UNLESS OTHERWISE NOTED ±2°.
THIS VALVE IS INTENDED FOR INSTALLATION ON A MANIFOLD FOR USE IN 4,000 PSI, TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- . THE ELECTRICAL POWER USED TO ENERGIZE THE VALVE SHALL BE DIRECT CURRENT IN ACCORDANCE WITH SPECIFICATION MIL-E-7894ASG. THE MANIFOLD MOUNTING FACE SHALL MATCH THE VALVE MOUNTING FACE EXCEPT THAT NO UNDERCUT FOR SEALS SHALL BE PROVIDED IN THE MANIFOLD. BOTH SURFACES SHALL BE FLAT WITHIN LIGHT BANDS.
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲ . THESE SEALING SURFACES SHALL BE PARALLEL TO THE VALVE MOUNTING FACE WITHIN .002 FIR.
THE APPLICABLE MS PART NUMBER, THE WORDS "4 WAY, 3 POSITION SELECTOR VALVE", THE RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON THE VALVE SO THAT THE MARKING IS VISIBLE WHEN THE VALVE IS MOUNTED.

REVISED

APPROVED

P.A. NAVY BUWEPS
Other Cust

TITLE **VALVE, MODULAR HYDRAULIC 4 WAY, 3 POSITION SELECTOR**
(FACE MOUNTED)
4000 PSI, TYPE III SYSTEM

MILITARY STANDARD
MS

PROCUREMENT SPECIFICATION MIL-
SUPERSEDES:
SHEET 3 OF 3

MILITARY SPECIFICATION

VALVE: AIRCRAFT HYDRAULIC SELECTOR - SOLENOID OPERATED - FOUR WAY, THREE POSITION

1. SCOPE

1.1 This specification covers face mounted and cartridge type, modular hydraulic, 4 way, 3 position, solenoid-operated, selector valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification - Selector valves shall be of the following types and classes:

Type I - Face mounted

Type II - Cartridge mounted

Class 1 - 0 to 4 GPM

Class 2 - 0 to 12 GPM

Class 3 - 0 to 25 GPM

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible, Waterproof

MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection, Process, Magnetic Particle
MIL-H-6875	Heat Treatment of Steels, (Aircraft Practice) For
MIL-H-7742	Screw Threads, Standard, Aeronautical
MIL-E-7894	Electrical Power, Aircraft Characteristics of
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III: Design, Installation, Tests and Data Requirements, General Specification for
MIL-D-70327	Drawings, Engineering and Associated Lists
Standards	
MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specifications and Standards, Use of
FED-TEST-STD No. 151	Metals; Test Methods
MS-33540	Safety Wiring - General Practices for
MS-20995	Wire-Lock
Drawings	
MS-	
MS-	

2.2 Other publications - Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification - The selector valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes - Materials and processes used in the manufacture of these valves shall conform to the following requirements and to the applicable specifications as defined in Section 2.

3.2.1 Metals - All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion, during the normal service life of the valve, which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency.

Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel - Close-fitting, sliding, steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts - Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts - Standard parts selected in accordance with section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the manufacturer's drawings.

3.4 Design and construction.

3.4.1 Envelope - The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification and MS drawings MS- and MS- .

3.4.2 Hydraulic fluid - The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range - The valves shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F. There shall be no evidence of external leakage or chatter when tested per 4.6.9.

3.4.4 Threads - Only class three threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals - Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying - Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety-wire shall be applied in accordance with standard drawings MS-33540 and MS-20995.

3.4.7 Retainer rings - Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valves.

3.4.8 Structural strength - The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight - The weight shall be kept to a minimum consistent with good design, and shall be specified on the applicable drawing.

3.4.10 Mounting position - The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control - The valve shall be designed to pass rated flow per 1.2 from pressure port to either cylinder port and from the other cylinder port to return when energized. When de-energized, flow shall be blocked between all ports.

3.4.12 Surface roughness - Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.4.13 Solenoid - The solenoid shall be of single coil construction, compact design, and of sufficiently rugged construction to withstand the mechanical shocks and stresses incident to their use in aircraft. Solenoids shall be designed for continuous duty with the solenoid totally enclosed

and shall be so designed that the hydraulic fluid can at no time come in contact with the electrical windings. The solenoid shall operate with direct current in accordance with Specification MIL-E-7894.

3.5 Interchangeability

3.5.1 Manufacturer's parts - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability - Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another housing without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification - Each valve shall have the identifying markings placed so that the identification can be read when the valve is installed. Each valve shall be permanently and legibly marked with the following information per MIL-H-7911.

Valve, Selector, 4 Way, 3 Position

MS-

Manufacturer's Part Number

Manufacturer's Name or Trademark

3.7 Workmanship

3.7.1 Quality - Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contamination. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection - All magnetizable highly stressed parts shall be subjected to magnetic inspection per Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection per Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated flow and operating pressure - The valves shall be designed to insure satisfactory operation and service life at rated flow per 1.2 and at an operating pressure of 4,000 psi, when tested per 4.6.2. The valves shall be capable of operation at 6,000 psi.

3.8.2 Proof pressure - The valves shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.4. There shall be no external leakage, permanent set or other damage.

3.8.3 Burst pressure - The valves shall be capable of withstanding a burst pressure of 10,000 psi, when tested per 4.6.13. There shall be no evidence of rupture of internal or external parts.

3.8.4 Valve Operation

3.8.4.1 Positions - When the two solenoids are de-energized, the flow through all ports shall be blocked. Refer to Figure 1. When solenoid number one is energized, the No. 1 load port shall be open to the pressure port and No.2 load port shall be open to return. When solenoid number two is energized, the No.2 load port shall be open to pressure and the No. 1 load port shall be open to return, when tested per 4.6.2. Refer to Figure 1.

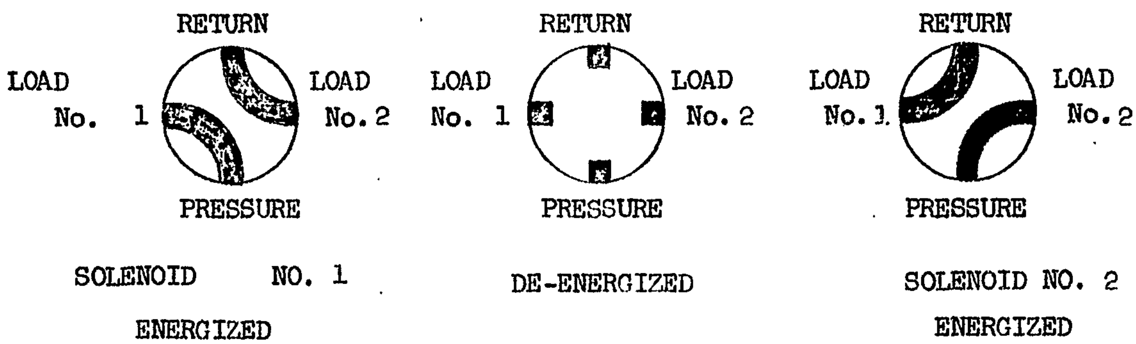


FIGURE 1

VALVE POSITIONS

3.8.4.2 Pressures - The valves shall operate satisfactorily with a pressure differential between the pressure port and return port no greater than 250 psi and with pressure on the pressure port in the range from return pressure of 250 psi to 6,000 psi, when tested per 4.6.2.

3.8.4.3 Electrical characteristics

3.8.4.3.1 The valves shall be designed for a 28 volt direct current system and shall be capable of satisfactory operation when 18 volts is applied at 4,000 psi and when 28 volts is applied at 6,000 psi throughout the ambient and operating temperature ranges, when tested per 4.6.9.

3.8.4.3.2 With 28 volts direct current applied to the coil terminals of the solenoids, the peak current drain shall not exceed 1.0 ampere, when tested per 4.6.7.

3.8.4.3.3 The time lapse of the solenoids shall not exceed 0.15 second between the instant of energizing and the pressure switch actuation, when tested per 4.6.8.

3.8.4.3.4 There shall be no breakdown of the dielectric material of the solenoids that could cause damage or coil failure, when 600 volts rms is applied per 4.6.6.

3.8.5 Internal leakage - The internal leakage of the valves shall not exceed the values of Table I, when tested per 4.6.3.

TABLE I

MAXIMUM ALLOWABLE INTERNAL LEAKAGE

PRESSURE APPLIED psi	PORT PLUGGED	SOLENOID ENERGIZED	LEAKAGE MEASURED at	LEAKAGE, CC PER MINUTE		
				CLASS 1 VALVE	CLASS 2 VALVE	CLASS 3 VALVE
4,000	-	-	load 1 & 2 return ports	8	10	12
4,000	load 1	#1	return ports	8	10	12
4,000	load 2	#2	return ports	8	10	12

3.8.6 Pressure drop - The pressure drop through the valves shall not exceed 100 psi when tested per 4.6.5. This pressure drop shall not include the pressure drop through the manifold or housing.

3.8.7 Endurance - The valves shall be capable of satisfactory operation for a total of 20,000 cycles at a rate of 12 to 16 cpm, when tested per 4.6.10.

3.8.8 Vibration - The valves shall be capable of withstanding vibration from 5 to 2,000 cps at an amplitude of 0.04 inches (0.08 inch total excursion) or 15G, whichever is limiting, in each of the three mutually perpendicular planes, when tested per 4.6.11.

3.8.9 Salt spray test - The valves shall function satisfactorily after exposure to 100 hours of salt spray, when tested per 4.6.12.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility - The manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests - The inspection and testing of selector valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of selector valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Qualification tests - The qualification tests shall consist ofthe following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

A. Examination of product per 4.6.1.

B. Proof pressure 4.6.4.

C. Pressure drop per 4.6.5.

D. Dielectric strength per 4.6.6.

E. Solenoid current drain per 4.6.7.

F. Timing test per 4.6.8.

G. Extreme temperature performance per 4.6.9.

H. Indurance per 4.6.10.

I. Vibration per 4.6.11.

J. Salt spray per 4.6.12.

K. Burst pressure per 4.6.13.

4.4 Acceptance tests - Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

A. Examination of product per 4.6.1.

B. Proof pressure per 4.6.4.

C. Actuation per 4.6.2.

D. Leakage per 4.6.3.

4.5 Test conditions

4.5.1 Test fluid - The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature - If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination - Standard fine air cleaner test dust or approved contaminent mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of particle	Percent by weight of total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	18 ± 3
over 40 micron	9 ± 3

4.5.4 Filtration - The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing - All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity. The test housing shall be acceptable to the procuring agency.

4.5.5.2 Acceptance test housing - The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration.

4.6 Test methods.

4.6.1 Examination of product - Each valve shall be carefully examined to determine conformance with the requirements of this specification for weight, workmanship, marking, conformance of dimensions to applicable drawings, and for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of

±5 micro-inches at the level being measured.

4.6.2 Actuation - The valve shall be cycled 15 times with an 18-volt source of direct current while 1,500 psi is applied to the pressure port. A cycle shall consist of energizing and de-energizing one solenoid and then energizing and de-energizing the other solenoid. Repeat this procedure 15 additional times with 4,000 psi applied to the pressure port. Repeat this procedure with 6,000 psi applied to the pressure port and using a 28-volt source to energize the solenoids. During this test, general functioning of the valve and the relation between energized and de-energized solenoids with respect to the spool position shall be in accordance with paragraph 3.8.4 of this specification.

4.6.3 Leakage - The valve shall be tested for internal leakage as specified in Table II. The pressure shall be held for a 5-minute period with leakage being measured the last 3 minutes. The fluid temperature shall be held at 95° ± 15°F. There shall be no evidence of external leakage.

TABLE II
LEAKAGE TESTS

VALVE CLASS	PRESSURE PSI	SOLENOID ENERGIZED	PORT PLUGGED	LEAKAGE MEASURED AT	MAXIMUM LEAKAGE RATE (cc/min)
1	4000	--	--	load # 1 & 2	8
1	4000	#1	load #1	return ports	8
1	4000	#2	load #2	return ports	8
2	4000	--	--	load # 1 & 2	10
2	4000	#1	load #1	return ports	10
2	4000	#2	load #2	return ports	10
3	4000	--	--	load # 1 & 2	12
3	4000	#1	load #1	return ports	12
3	4000	#2	load #2	return ports	12

4.6.4 Proof pressure - This test shall be performed at a temperature of 450° ± 15°F for qualification testing and 95° ± 15°F for acceptance testing. With load port #1 plugged and solenoid #1 energized, pressure shall be applied to the pressure port at a rate not to exceed 25,000 psi per minute until 6,000 psi is reached. The 6,000 psi proof pressure shall be held for at least 2 minutes. With load port #2 plugged and solenoid #2 energized, this procedure shall be repeated. With both solenoids de-energized, pressure shall be applied to the pressure and return ports at a rate not to exceed 25,000 psi per minute until 6,000 psi is reached. The 6,000 psi shall be held for at least 2 minutes. A hand pump may be used for this test if desired.

4.6.5 Pressure drop - For the rated flow of each class valve determine the pressure drop between the pressure port and each load port, and between each load port and the return port. A back pressure of 200 psi minimum shall be maintained on the downstream side of the ports being tested. This test shall be run at a fluid temperature of +90° ± 15°F and the pressure drop between the two ports being tested shall not exceed 75 psi for the face-mounted unit (TYPE I) or 100 psi for the cavity-mounted unit (TYPE II). The pressure drop does not include the pressure drop through the test manifold or housing, but does include the pressure drop through the seals and spacers.

4.6.6 Dielectric strength - The solenoids shall be soaked at not less than 650°F for 8 hours or longer. Apply 600 volts root mean square between each solenoid and ground for a period of 60 seconds while the temperature is held at 650°F. There shall be no failure or evidence of damage to insulation.

4.6.7 Solenoid current drain - Apply 28 volts direct current to each solenoid. The current drain shall not exceed 1.0 ampere for each solenoid at 95° ± 15°F.

4.6.8 Timing test - An oscillograph shall be used to plot electrical input to the solenoid and pressure at the load port, simultaneously. With 4,000 psi applied to the pressure port and cylinder #1 port plugged, energize solenoid #1. The time lapse between electrical application and pressure rise to 4,000 ± 50 psi at load #1 port shall not exceed .15 second. Repeat this procedure energizing solenoid #2. The time lapse between electrical application and pressure rise to 4,000 ± 50 psi at load #2 port shall not exceed .15 second. The temperature shall be 95° ± 15°F for this test.

4.6.9 Extreme temperature performance

4.6.9.1 Low temperature operation - The test set-up shall be similar to Figure 2. The test set-up shall be soaked at a temperature not warmer than -65°F for 8 hours or longer. At the end of this period, 1,500 psi shall be applied to the pressure port and solenoid #1 energized by an 18-volt source of electricity. The valve shall shift and allow flow from the pressure port to load #1 port. De-energize solenoid #1 and the valve shall shift back to its neutral position with no flow between the ports. Energize solenoid #2 by an 18-volt source of electricity; the valve shall shift and allow flow from the pressure port to cylinder #2 port. De-energize the solenoid and the valve shall shift back to the neutral position with no flow between ports. The fluid temperature shall then be raised to not greater than -20°F and the pressure increased to 4,000 psi, and the above procedure repeated. The pressure drop from the pressure port to the load ports shall be checked

for this portion of the Low Temperature Operation Test. The pressure drop from the pressure port to the load ports shall not exceed 75 psi for the face-mounted unit (TYPE I) or 100 psi for the cavity-mounted unit (TYPE II) at rated flow for the class valve being tested. After completion of the above test, and the temperature held not warmer than -20°F, the pressure shall be increased to 6,000 psi. The voltage required to fully open the valve shall then be determined and this value shall not exceed 28 volts. Decrease the solenoid voltage and determine the coil voltage at which the valve will fully close.

4.6.9.2 Rapid warm-up - The test set-up for the Low Temperature Test may be used for this test. The fluid shall be warmed up rapidly from -20°F by flowing through the relief valve or by use of a heater. When the fluid temperature reaches +27°F, solenoid #1 shall be energized with a maximum of 18 volts for 5 seconds. This shall permit rated flow to pass through the valve. At the end of 5 seconds the solenoid shall be de-energized. Solenoid #2 shall be energized in a like manner for 5 seconds permitting rated flow to pass through the valve. At the end of 5 seconds, solenoid #2 shall be de-energized. The above procedure shall be repeated at approximately 47°F increments until the fluid reaches 450°F. At each of these checks, the test valve shall fully open each time a solenoid is energized and shall fully close each time the solenoids are de-energized.

4.6.9.3 High temperature operation and leakage - The test set-up shall be similar to Figure 2. With the system bled of air and pressurized at 4,000 psi, temperature in the temperature control box shall be maintained at not less than 450°F for 6 hours or longer. The valve shall be de-energized during this period. At the end of this period and with

4,000 psi applied to the pressure port, solenoid #1 shall be energized. The coil voltage required to fully open the valve shall not be greater than 18 volts. The coil voltage shall be decreased and the voltage at which the valve fully closes shall be recorded. The same procedure shall be repeated except this time solenoid #2 shall be energized and de-energized. This shall be repeated 4 times for each solenoid. No long waiting period between operations is necessary. Leakage test shall be performed per paragraph 4.6.3 while the valve is at a temperature of 450°F. The allowable leakage rate shall be increased by a factor of $2\frac{1}{2}$ over those given in paragraph 4.6.3. There shall be no external leakage during this test.

4.6.10 Endurance - The test set-up shall be similar to Figure 2. The valve shall be subjected to a total of 20,000 cycles of shifting the spool to the three positions by energizing and de-energizing the two solenoids at rated flow while a pressure of 4,000 psi is applied to the pressure port. The endurance test shall be conducted while the valve undergoes a time-temperature spectrum as shown in Figure 3. The 20,000 cycles shall be accomplished by going through the spectrum four times. The valve shall be cycled at the rate of 12 to 16 cycles per minute. Prior to going through a spectrum, the valve and fluid shall be maintained at a temperature not warmer than -65°F for 8 hours or longer. After completing the four spectrums, the valve shall be tested for leakage and shall meet the requirements as specified in paragraph 4.6.3. No external leakage shall occur during this test.

4.6.11 Vibration test

a. With the fluid temperature maintained at 95° +15°F, the valve shall be cycled at a rate of 12 to 16 cpm. Cycling shall be

accomplished by energizing and then de-energizing one solenoid and then the other. Rated flow shall be allowed to pass through the valve when it is in the open position. While the valve is being cycled, it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2,000 cps for 30 minutes. The amplitude shall be .04 inches (.08 inches total excursion) or 15 G, whichever is limiting. This test shall be repeated two times and during this time the frequency of any and all resonant points (natural frequencies) shall be noted. Vibrate the valve for 90 minutes at the most severe resonant frequency noted above at .08 inches total excursion or 15 G, whichever is less severe. If no resonant frequency is noted, the valve shall be vibrated at 500 cps.

b. Repeat (a) changing the direction of vibration 90° horizontally.

c. Repeat (a) changing the direction of vibration to vertical.

d. After completion of (a), (b) and (c), the valve shall be checked per paragraph 4.6.3 except that the allowable leakage shall be increased by 50 per cent.

e. The valve shall then be removed from the test block and visually inspected for mechanical failure.

f. The valve shall be placed back in the test set-up and with a 250 psi differential pressure between the pressure port and the return port, the valve shall be cycled electrically and shall pass rated flow from the pressure port to the load ports.

4.6.12 Salt spray test - The valve shall be subjected to a 100-hour salt spray test in accordance with Federal Test Method Standard No. 151, Method 811. At the conclusion of this test period, the solenoid shall be air dried for 6 hours, then subjected to a dielectric test per paragraph 4.6.6. With 4,000 psi applied to the pressure port, the valve shall be cycled by energizing the solenoids with no more than 18 volts and the valve shall open and pass rated flow.

4.6.13 Burst pressure test - With 5,000 psi applied to the return port, pressure shall be applied to the pressure port and the two cylinder ports at a rate not to exceed 25,000 psi per minute until 10,000 psi is reached. This pressure shall be held for at least two minutes. There shall be no rupture of external or internal parts. The fluid temperature shall be $95° \pm 15°F$ for this test.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging - Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments - Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

✓

Stock No. as specified in the purchase document

Name of part

MS part no.

Month and year of manufacture

Class or size

6. NOTES

6.1 Intended use - The selector valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891 and operating with hydraulic fluid conforming to Specification MIL-H-8446. The valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering data - Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number

(c) Class

(d) Federal stock number

(e) Pressure setting

6.3 Qualification - With respect to products requiring qualifications, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders

for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D.C., however, information pertaining to qualification of products may be obtained from the Commanding Officer, U.S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

Preparing activity:

Navy - Bureau of Naval Weapons

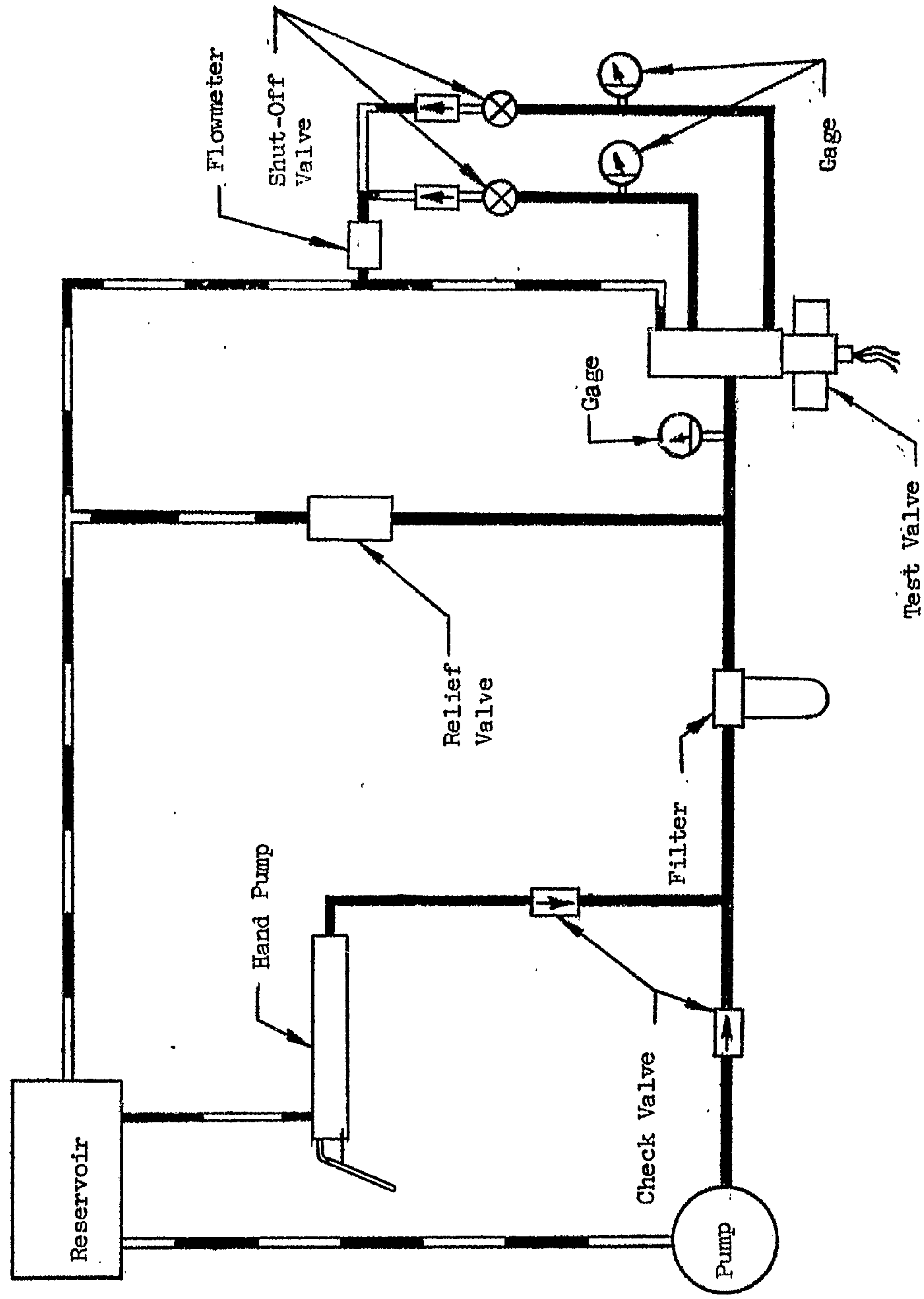

Flowmeter
Shut-Off Valve
Gage
Gage
Test Valve
Relief Valve
Filter
Hand Pump
Check Valve
Reservoir
Pump

FIGURE 2

NOTES:

1. Rate of temperature rise or decay may vary within the shaded area shown
2. Approximately 6 hours of endurance cycling are to be run in one day
3. Ambient temperature shall be maintained at 650°F during the time from the 2nd hour through the 5th hour of spectrum shown

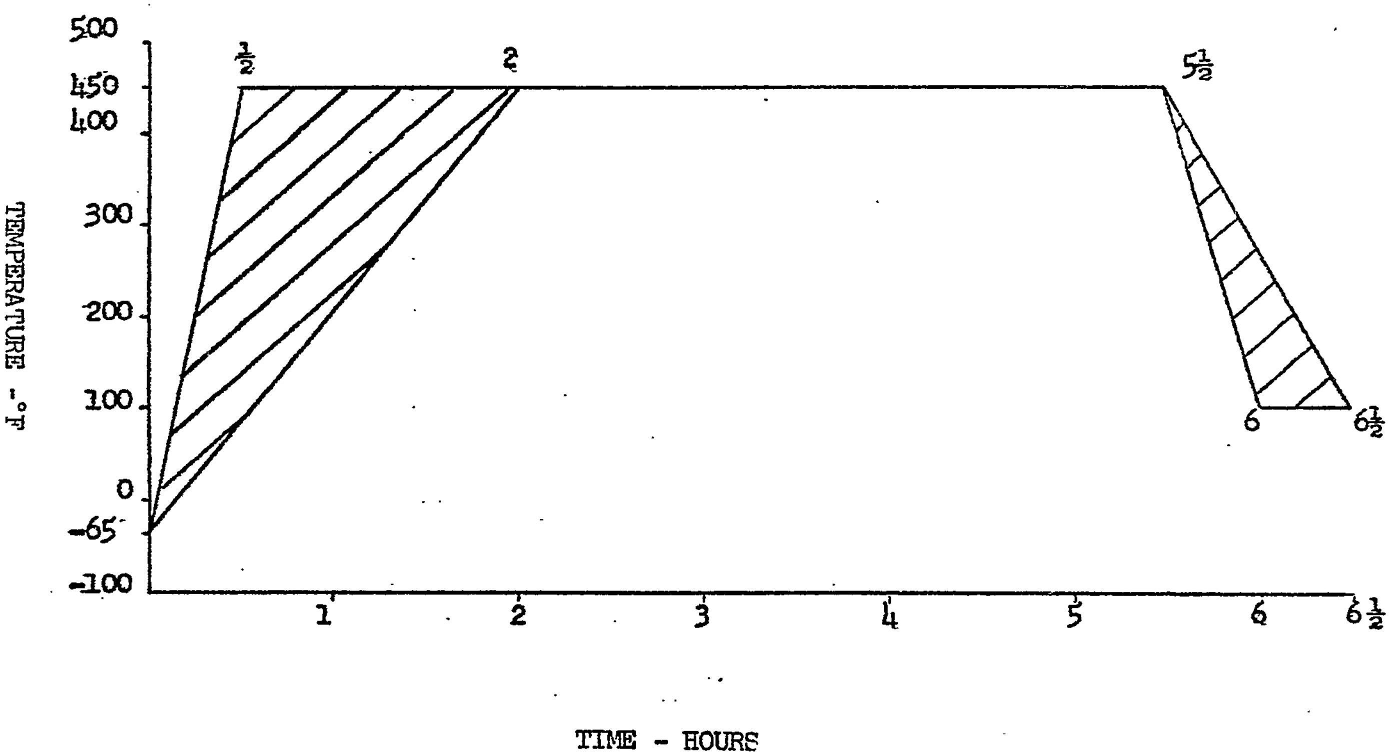
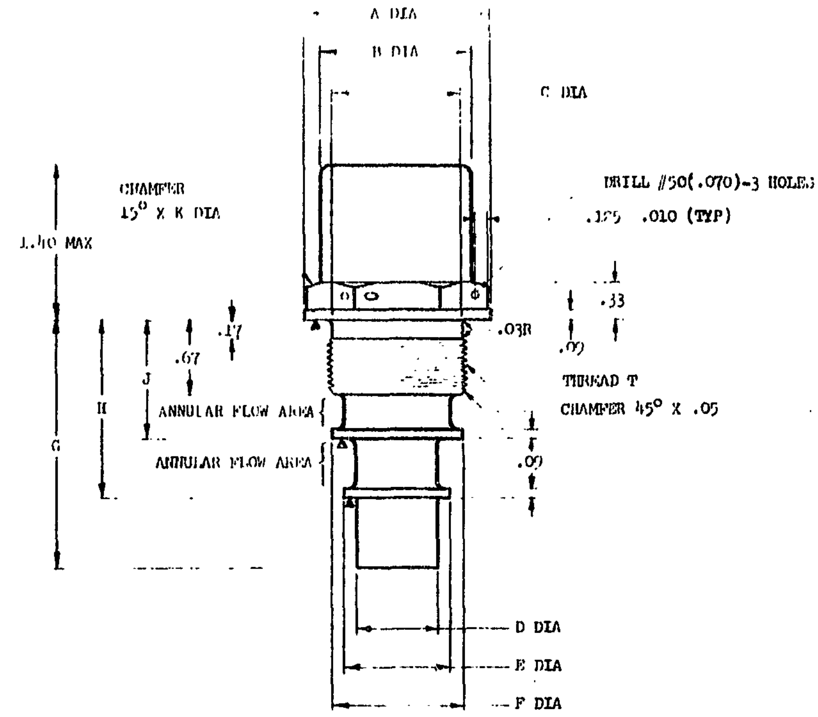


FIGURE 3

APPENDIX XII

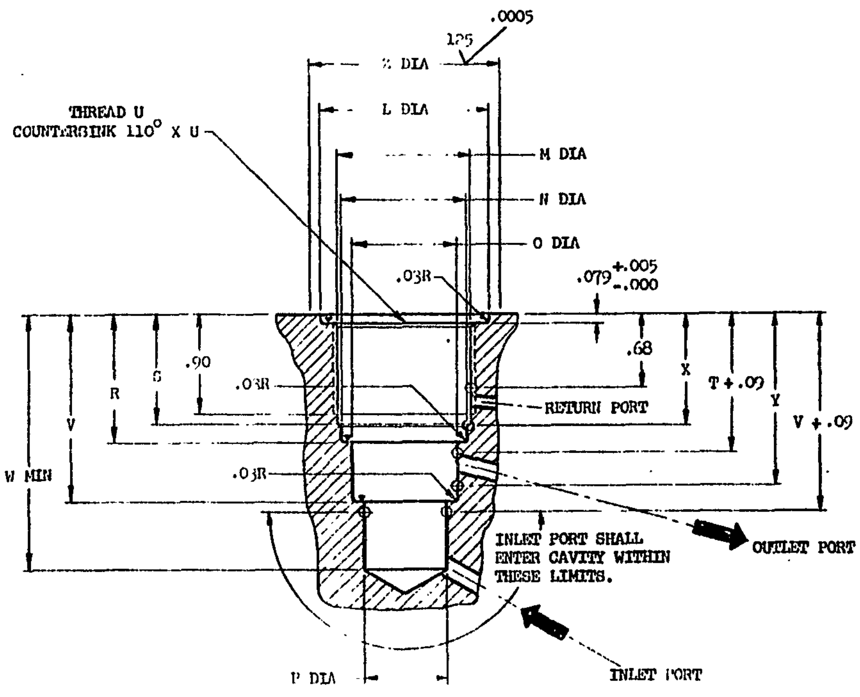
Suggested MIL Specification for Priority Valve
Suggested MS Standard for Priority Valve

FED. SUP CLASS



VALVE DATA

PART NUMBER	THREAD T	A DIA	B DIA MAX	C DIA +.000 -.005	D DIA MAX	E DIA +.000 -.002	F DIA +.000 -.002	G MAX	H +.000 -.003	J +.000 -.003	K DIA	FLOW RATE GPM	WEIGHT POUNDS
MS -1	1 1/4-18 NEF-3A	1.66	1.37	1.170	.74	.943	1.182	2.22	1.600	1.070	1.43	4	
MS -2	1 5/8-18 NEF-3A	2.03	1.75	1.545	1.10	1.370	1.557	3.05	2.060	1.150	1.75	12	
MS -3	1 15/16-16N-3A	2.41	2.00	1.848	1.40	1.620	1.807	3.38	2.240	1.280	2.00	25	



REVISED

APPROVED

P.A. Other Cust	TITLE VALVE, PRIORITY MODULAR HYDRAULIC 4000 PSI TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 1 OF 2

CAVITY DATA

CAVITY FOR PART NUMBER	THREAD U	L DIA	M DIA	N DIA +.00[illegible] -.000	O DIA +.00[illegible] -.000	P DIA	S	R +.003 -.000	V +.003 -.000	W MIN	X	Y	Z DIA MIN
MS -1	1 1/4-18 NEF-3B	1.500 +.00[illegible] -.000	1.16[illegible] +.00[illegible]1 -.0000	1.127	[illegible]	.77	.78	1.18[illegible]	1.67[illegible]	[illegible].26	1.01	1.54	1.7[illegible]
MS -2	1 5/8-18 NEF-3B	1.875 +.000 -.000	1.5040 +.0081 -.0000	1.[illegible]	1.[illegible]75	1.17	1.04	1.[illegible]	[illegible].13[illegible]	[illegible]	1.0[illegible]	.90	[illegible].0[illegible]
MS -3	1 15/16-16N-3B	2.250 +.003 -.000	1.8[illegible]08 +.0[illegible]35 -.0000	1.61[illegible]	1.6[illegible]	1.42	1.16	1.[illegible]	[illegible].31[illegible]	3.44	1.[illegible]	[illegible].18	2.47

[illegible] REQUIREMENTS

TEMPERATURE LIMITS - 550°F FLUID AND [illegible]°F AMBIENT MAXIMUM. VALVE SHALL FUNCTION AT -[illegible] °F.
PRESSURE - OPERATING [illegible] PSI, PROOF [illegible]000 PSI, BURST 10,000 PSI
FLUID - SPECIFICATION MIL-H-[illegible]
SEALS - SPECIFICATION MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE
PRESSURE DROP - [illegible] PSI MAXIMUM AT RATED FLOW

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL ▲) SHALL BE 1[illegible] RHR. ALL OTHER SURFACES 1[illegible] RHR. REFERENCE SPECIFICATION MIL-STD-10.
TOLERANCES: THE SEALING SURFACES OF VALVE DIAMETERS "E" AND "F" SHALL BE PARALLEL TO SEALING SURFACE OF VALVE DIAMETER "A" WITHIN .00[illegible] FIR. THE SEALING SURFACE OF DIAMETER "A" SHALL BE PERPENDICULAR TO AXIS OF THREAD "T" WITHIN .001 FIR. VALVE DIAMETERS "E" AND "F" SHALL BE CONCENTRIC TO AXIS OF THREAD "T" WITHIN .00[illegible] FIR. CAVITY SEALING SURFACES DEFINED BY "L", "N", AND "O" DIAMETERS SHALL BE PARALLEL TO SURFACE "[illegible]" WITHIN .00[illegible] FIR. THE SURFACE DEFINED BY DIAMETER "Z" SHALL BE PERPENDICULAR TO THE AXIS OF THREAD "U" WITHIN .001 FIR. CAVITY DIAMETERS "N" AND "O" SHALL BE CONCENTRIC WITH THE AXIS OF THREAD "U" WITHIN .00[illegible] FIR.
TOLERANCES UNLESS OTHERWISE NOTED: DETAIL ±.01[illegible]; ANGULAR ±[illegible].
THIS VALVE INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN [illegible] PSI TYPE III HYDRAULIC SYSTEM WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL- .
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-77[illegible].
THE APPLICABLE MS PART NUMBER, THE WORDS "PRIORITY VALVE", AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED SO THAT THE IDENTIFICATION IS VISIBLE WHEN THE VALVE IS INSTALLED.

REVISED

APPROVED

P.A. Other Cust	TITLE VALVE, PRIORITY MODULAR HYDRAULIC 4000 PSI TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION	SUPERSEDES.	SHEET 2 OF 2

MILITARY SPECIFICATION
VALVES: AIRCRAFT HYDRAULIC PRIORITY

1. SCOPE

1.1 This specification covers cartridge type, modular hydraulic, priority valves, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Priority valves shall be of the following classes:

Class 1 - 0 to 4 GPM

Class 2 - 0 to 12 GPM

Class 3 - 0 to 25 GPM

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible, Waterproof
MIL-I-6866	Inspection, Penetrant-Method of
MIL-I-6868	Inspection, Process, Magnetic Particle
MIL-H-6875	Heat Treatment of Steels, (Aircraft Practice) For
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft
MIL-H-8891	Hydraulic Systems, Type III; Design, Installation, Tests and Data Requirements, General Specification for
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specifications and Standards, Use of
FED-TEST-STD No. 151	Metals; Test Methods

MS-33540	Safety Wiring-General Practices For
MS-20995	Wire-Lock

Drawings

MS-
MS-

2.2 Other publications - Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification - The priority valve furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes - Materials and processes used in the manufacture of these valves shall conform to the following requirements and to the applicable specifications as defined in Section 2.

3.2.1 Metals - All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion, during the normal service life of the valve, which may result from such conditions as dissimilar metal combinations, moisture, salt spray, and high-temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring agency. Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces

in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel - Close-fitting, sliding, steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts - Plastic parts shall be used only with the approval of the procuring activity for each application.

3.3 Parts - Standard parts selected in accordance with section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the manufacturer's drawings.

3.4 Design and construction.

3.4.1 Envelope - The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification and MS drawings MS- and MS- .

3.4.2 Hydraulic fluid - The valves shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.3 Temperature range - The valves shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F. There shall be no evidence of external leakage, when tested per 4.6.4.

3.4.4 Threads - Only class three threads conforming to Specification MIL-S-7742 shall be used.

3.4.5 Seals - Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.6 Safetying - Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety-wire shall be applied in accordance with standard drawings MS-33540 and MS-20995.

3.4.7 Retainer rings - Except where they are positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valves.

3.4.8 Structural strength - The valves shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.9 Weight - The weight shall be kept to a minimum consistent with good design, and shall be no greater than specified on the applicable MS drawing.

3.4.10 Mounting position - The valves shall satisfy the performance requirements when mounted in any position.

3.4.11 Flow control - The valves shall be designed to pass rated flow per 1.2 from inlet port to outlet. The valves shall be capable of passing the rated flow in the reverse direction with a pressure drop not exceeding 25 psi, when tested per 4.6.3 .

3.4.12 Surface roughness - Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's parts - All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components of such assembled units need not be interchangeable.

3.5.2 Maintainability - Modular valves shall be self-contained components such that a valve may be removed from one housing and inserted into another housing without any detail disassembly, readjustment of setting, or impairment of function.

3.6 Identification - Each valve shall have the identifying markings placed on the hex-head or the flange so that the identification can be read when the valve is installed in the manifold cavity. Each valve shall be permanently and legibly marked with the following information per MIL-H-7911.

Valve, Priority

MS-

Manufacturer's Part Number

Manufacturer's Name or Trademark

3.7 Workmanship

3.7.1 Quality - Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging valves to assure that the components are clean and free of contamination. All parts shall be free

from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection - All magnetizable highly stressed parts shall be subjected to magnetic inspection per Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection per Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Rated pressure - The valves shall be designed to operate satisfactorily in a hydraulic system having a rated pressure of 4,000 psi, when tested per 4.6.3. The vent port shall be designed for operating pressure to 2000 psi.

3.8.2 Operating pressures - The valves shall be designed to insure satisfactory operation and service life throughout the operating pressure range from 0 to 4,000 psi, when tested per 4.6.[illegible]. The valve shall be capable of operation at 6,000 psi.

3.8.3 Proof pressure - The valves shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.[illegible] and there shall be no evidence of external leakage, permanent set, or other damage.

3.8.4 Burst pressure - The valves shall be designed so as not to burst at any pressure below 10,000 psi, when tested per 4.6.8.

3.8.5 Pressure setting

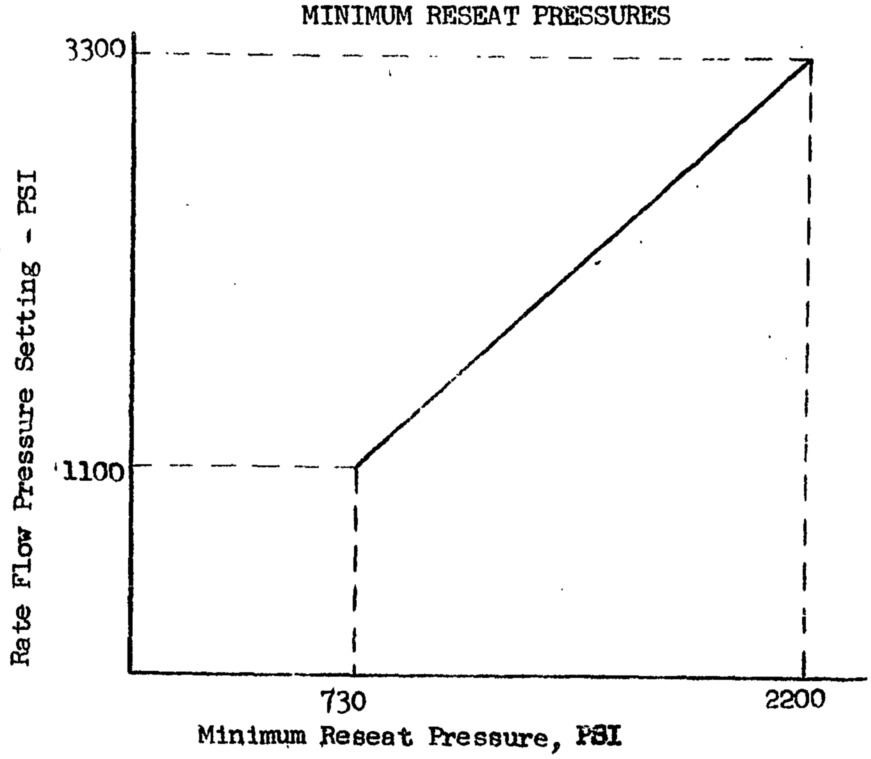
3.8.5.1 Range - The valves shall be capable of being set by means of a power driven pump to give rated flow at any pressure from 1100 psi to 3300 psi, inclusive, when tested per 4.6.3.

3.8.5.2 Inlet pressure - For any return port pressure from zero to the full flow pressure less 50 psi, the inlet pressure shall not vary more than 6 per cent to maintain rated flow, when tested per 4.6.3.

3.8.5.3 Reseat pressure - With zero back pressure and upon decreasing inlet pressure, the valves shall reseat at a pressure not less than 67 per cent of the rated flow pressure setting, when tested per 4.6.3. The minimum reseat pressures shall be in accordance with Figure 1.

Figure 1

MINIMUM RESEAT PRESSURES



Reseat pressure shall be defined as that pressure, during decreasing pressure, at which the leakage rate does not exceed 12cc per minute with zero back pressure, when tested per 4.6.3.

3.8.5.4 Cracking pressure - Cracking pressures shall not be less than reseat pressures with the back pressure varying from zero to cracking pressure. Cracking pressure shall be defined as that inlet pressure, during increasing pressure, at which the valve exceeds the maximum reseat leakage of 12cc per minute, when tested per 4.6.3.

3.8.6 Internal leakage - Internal leakage shall not exceed the values of Table I, when tested per 4.6.3.

TABLE I

MAXIMUM ALLOWABLE INTERNAL LEAKAGE

AT RESEAT PRESSURE SETTING	DURING INCREASING AND DECREASING PRESSURES		
	AT 1/4 OF RESEAT PRESSURE	AT 1/2 OF RESEAT PRESSURE	AT 3/4 OF RESEAT PRESSURE
12 cc/min with 0 back pressure	6 cc/min	6 cc/min	6 cc/min

3.8.7 Reverse flow pressure drop - The valves shall be capable of passing rated flow through the valve in the reverse direction and the pressure drop shall not exceed 25 psi when tested per 4.6.3. All measurements of pressure drop shall be for the module only. The pressure drop for the test housing shall be determined separately and subtracted from the values obtained during module testing.

3.8.8 Surge pressure - The valves shall be capable of withstanding a surge pressure of 2200 psi at a rate of 35 cycles per minute, when tested per 4.6.5. The valves shall show no evidence of malfunctioning or damage.

3.8.9 Vibration - The valves shall be capable of withstanding vibrations from 5 to 2,000 cps with an amplitude of 0.04 inch (0.08 inch total excursion) or 15G, whichever is limiting, along three mutually perpendicular axes, when tested per 4.6.7. The valves shall meet the leakage requirements of Table I increased to a maximum of two times the stated values.

3.8.10 Endurance - When the valve has been subjected to 50,000 cycles of operation per 4.6.6, internal leakage at 1/4, 1/2 and 3/4 of the cracking pressure setting shall not exceed 6 cc/per minute.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility - The manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests - The inspection and testing of priority valves shall be classified as follows:

(a) Qualification tests

(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Samples of priority valves for qualification tests shall consist of one specimen of each class valve upon which qualification is desired.

4.3.1.2 The specimen shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.3 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F, using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Qualification tests - The qualification tests shall consist of the following tests which shall be conducted in the order listed. All tests are described under 4.6 of this specification.

A. Proof pressure per 4.6.2

B. Normal temperature performance per 4.6.3

C. Extreme temperature performance per 4.6.4

D. Surge pressure per 4.6.5

E. Endurance per 4.6.6

F. Vibration per 4.6.7

G. Burst pressure per 4.6.8

4.4 Acceptance tests - Acceptance tests shall be performed on individual valves or lots which have been submitted under contract to determine conformance of the products or lots with requirements set forth in this specification prior to acceptance. Each valve shall be subjected to the following tests:

A. Examination of product per 4.6.1

B. Proof pressure per 4.6.2

C. Pressure setting per 4.6.3.2

D. Decreasing pressure leakage per 4.6.3

E. Increasing pressure leakage per 4.6.3

F. Reverse flow pressure drop per 4.6.3

4.5 Test conditions

4.5.1 Test fluid - The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature - If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the valve ports. During all soaking periods, the component shall be

bled of air and inert gas and maintained full of fluid.

4.5.3 Contamination - Standard fine air cleaner test dust or approved contaminant mixture shall be added through the reservoir of the test set-up before start of qualification tests. The reservoir shall incorporate a mixer or shall be externally excited so as to keep the contaminant continuously agitated or mixed within the fluid. Test dust shall be added until one gram of dust per three gallons system fluid capacity has been introduced. The test dust shall be apportioned as follows:

Size of particle	Percent by weight of total
0 to 5 micron	39 ± 2
5 to 10 micron	18 ± 3
10 to 20 micron	16 ± 3
20 to 40 micron	18 ± 3
over 40 micron	9 ± 3

4.5.4 Filtration - The test fluid shall be continuously filtered through a filter which has a maximum opening that does not exceed 25 microns. The filter and element used shall be satisfactory for the temperature range encountered, and cleaned or changed regularly to prevent clogging.

4.5.5 Test housing

4.5.5.1 Qualification test housing - All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity. The test housing shall be acceptable to the procuring agency.

4.5.5.2 Acceptance test housing - The tests in 4.4 may be conducted in the qualification test housing or in a housing having any other external configuration

4.6 Test methods.

4.6.1 Examination of product - Each valve shall be carefully examined to determine conformance with the requirements of this specification for weight, workmanship, marking, conformance of dimensions to applicable drawings, and for any visible defects. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ± 5 micro-inches at the level being measured.

4.6.2 Proof pressure test - With the outlet port plugged, pressure shall be applied to the pressure port at a rate not exceeding 25,000 psi per minute until 6,000 psi is reached. The proof pressure shall be held for at least two minutes, and there shall be no evidence of external leakage, permanent set or other damage. For this test the component and the fluid shall be stabilized at a temperature of 95°F ± 15°F for acceptance and 450°F ±15°F for qualification.

4.6.3 Normal temperature performance

4.6.3.1 Minimum setting - A typical set-up for this test is shown in Figure 5. The power driven pump shall be used. Leakage is to be observed at the outlet port during the third minute of a 3-minute waiting period. The valve shall be set and tested as follows:

4.6.3.1.1 Rated flow pressure - Adjust the valve to produce rated flow at the minimum pressure setting of 1100 psi with the back pressure held at rated flow pressure less 50 psi. Then, maintaining the flow constant, vary the back pressure from as near zero as possible to 50 psi less than the noted inlet pressure. The inlet pressure shall not vary by more than 6 percent of its noted value.

4.6.3.1.2 Reseat pressure - Decrease inlet pressure gradually from rated flow pressure until leakage not greater than 12 cc/min. can be determined, during the third minute of a 3-min. period. This pressure shall be considered the reseat pressure and its value shall not be less than that specified by Figure 1. The measurement of reseat pressure shall be made with zero back pressure.

4.6.3.1.3 Decreasing pressure leakage - Pressure shall be gradually decreased from reseat pressure determined in paragraph 4.6.3.1.2 and leakage shall be observed at pressures of 3/4, 1/2 and 1/4 of the reseat pressure setting of the valve. Leakage shall not exceed 6 cc/minute. When specified this test shall be used for acceptance.

4.6.3.1.4 Increasing pressure leakage - The pressure shall then be gradually increased from 1/4, to 1/2, and 3/4 of the reseat pressure setting and the leakage shall be rechecked and shall not exceed 6 cc/min. Continue to increase pressure to that determined as reseat pressure by the test of para. 4.6.3.1.2. Leakage at that pressure shall not exceed 12 cc/min. When specified this test shall be used for acceptance.

4.6.3.1.5 Cracking pressure and back pressure - Raise the inlet pressure gradually to cracking pressure. Cracking pressure is defined as that inlet pressure at which the valve exceeds the maximum reseat leakage of 12 cc/minute upon increasing pressure. The outlet port shall be open. The cracking pressure shall in no case be less than the reseat pressure.

4.6.3.1.6 Reverse flow pressure drop - Rated flow shall be passed through the valve in the reverse direction. The pressure drop shall not exceed 25 psi. The temperature shall be 95°F ± 15°F for acceptance.

4.6.3.2 Maximum setting - The tests outlined under the paragraphs entitled "Minimum Setting" shall be repeated with the valve adjusted to produce the maximum rated flow pressure of 3300 psi. (Pressure setting for acceptance testing shall be as specified in the procurement document.)

4.6.4 Extreme temperature performance -

4.6.4.1 Low temperature performance - A typical set-up for this test is shown in Figure 2. The test set-up shall be stabilized at a temperature not warmer than -65°F for a minimum period of 8 hours. With the test valve adjusted for maximum rated flow pressure (3300 psi) fluid shall be pumped through the valve by means of a hand pump. Inlet pressure shall gradually be decreased until reseat pressure (as defined in 4.6.3.1.2) is determined. Reseat pressure shall not be less than 2200 psi. The pressure at which rated flow occurs shall be determined and recorded. Repeat this test at -20°F.

4.6.4.2 High temperature performance - Using the test set-up shown in Figure 5, the test valve shall be adjusted to produce the maximum rated flow pressure (3300 psi). The valve and hydraulic fluid shall be stabilized at 450°F for a minimum period of 4 hours. The power driven pump tests outlined in the paragraph entitled "Maximum Setting" shall be repeated. Internal leakage shall not be greater than 6.0 cc/minute at or below 3/4 of the reseat pressure nor greater than 12.0 cc/minute at the minimum reseat pressure. Reseat pressure shall not be less than 2200 psi as shown in Figure 1. The cracking pressure setting shall not be greater than that observed at room temperature.

4.6.5 Surge pressure test

Using a test set-up similar to that of Figure 6 an impulse pressure of 2200 psi shall be applied to the pressure port of the test valve followed by a reduction of pressure to not more than 100 psi. The surge pressure shall be applied at a rate not slower than 35 cycles per minute for a total period of one minute. The rate of pressure rise shall be 50,000 ± 5,000 psi/second. Leakage shall be measured at the outlet port of the test valve and shall not exceed 6.0 cubic centimeters over the total number of pressure impulse cycles. The surge pressure shall be directed to the test valve by cycling a 3 way, 2 position selector valve as shown in Figure 6. This test shall be conducted at 95 ± 15°F.

4.6.6 Endurance test - A typical set-up for life cycling is shown in Figure 3. The Endurance Test shall consist of adjusting the valve to the maximum rated flow pressure setting (3300 psi) at normal temperature and cycling at the rate of 17-19 cpm for 50,000 cycles. Each cycle shall consist of imposing rated flow through the valve, and reducing pressure to substantially zero. These cycles shall be accomplished while the valve undergoes a time-temperature spectrum as shown in Figure 4. This spectrum shall be repeated seven times during endurance testing with an overnight low temperature soak between each run. The first, fourth, and seventh repetition of this spectrum shall begin at -65°F while the second, third, fifth and sixth repetitions shall begin at room temperature. After completion of this test, internal leakage at 1/4, 1/2 and 3/4 of the cracking pressure setting, shall not exceed 6cc/per minute. Determine the pressure at which the valve reseats. This value shall not be less than 2200 psi.

4.6.7 Vibration test

a. Prior to this test the valve shall be adjusted to each extreme position or pressure setting a minimum of 15 times. With the fluid temperature maintained at 95 ± 15°F the priority valve shall be set for rated flow at 2500 psi. The valve shall be cycled at the rate of 15 to 20 cpm by imposing rated flow through the valve and then reducing pressure to substantially zero. While the valve is being cycled in this manner it shall be vibrated in a horizontal direction with the frequency varying between 5 and 2000 cps in 30 minutes. The amplitude shall be 0.04 inch (0.08 inch total excursion) or 15G, whichever is limiting. This test shall be repeated two times and during this time the frequency of any and all resonant points (natural periods) shall be noted. The valve shall be vibrated for 90 min. at the most critical resonant frequency noted above at 0.08 inch total excursion or 15G, whichever is least severe. If there are no resonant frequencies, the valve shall be vibrated at 500 cps. Upon completion of the 90 minute test, the rated flow pressure setting shall be checked at a frequency 10% above or below the natural frequency and shall not have changed more than one percent from the original setting.

b. Repeat (a) changing the direction of vibration 90° horizontally.

c. Repeat (a) changing the direction of vibration to vertical.

d. After completion of (a), (b) and (c) internal leakage at the reseat pressure and at 1/4, 1/2 and 3/4 of the reseat pressure setting, shall be a maximum of two times the values permitted in the paragraph entitled "Maximum Setting." Adjust the valve to produce rated flow at 3300 psi with 3250 psi back pressure. Then maintaining the flow constant, vary the back pressure from as near zero as possible to 3250 psi. The inlet pressure shall not vary by more than 3 percent of its noted value.

4.6.8 Burst pressure test - With the outlet port plugged, pressure shall be applied to the pressure port until 10,000 psi is reached. This pressure shall be held for 2 minutes. There shall be no rupture of external or internal parts. The fluid temperature shall be 450 ± 15°F for this test. This test shall be repeated with the pressure port plugged and pressure applied to the free flow port.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging - Each component shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component shall then be wrapped or bagged in grade A grease-proof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments - Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document

Name of Part

MS part no.

Month and year of manufacture

Class or size

6. NOTES

6.1 Intended use - The priority valves covered by this specification are intended for use in aircraft and missile hydraulic systems covered by Specification MIL-H-8891 and operating with hydraulic fluid conforming to Specification MIL-H-8446. The valve is further intended for use in a manifolded or packaged type system.

6.2 Ordering data - Procurement documents should specify the following:

(a) Title, number, and date of this specification

(b) MS part number

(c) Class

(d) Federal stock number

(e) Pressure setting

6.3 Qualification - With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D.C.; however, information pertaining to qualification of products may

be obtained from the Commanding Officer, U.S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

Preparing activity:

Navy - Bureau of Naval Weapons

FIGURE 2

Typical Schematic for Low Temperature Performance Test

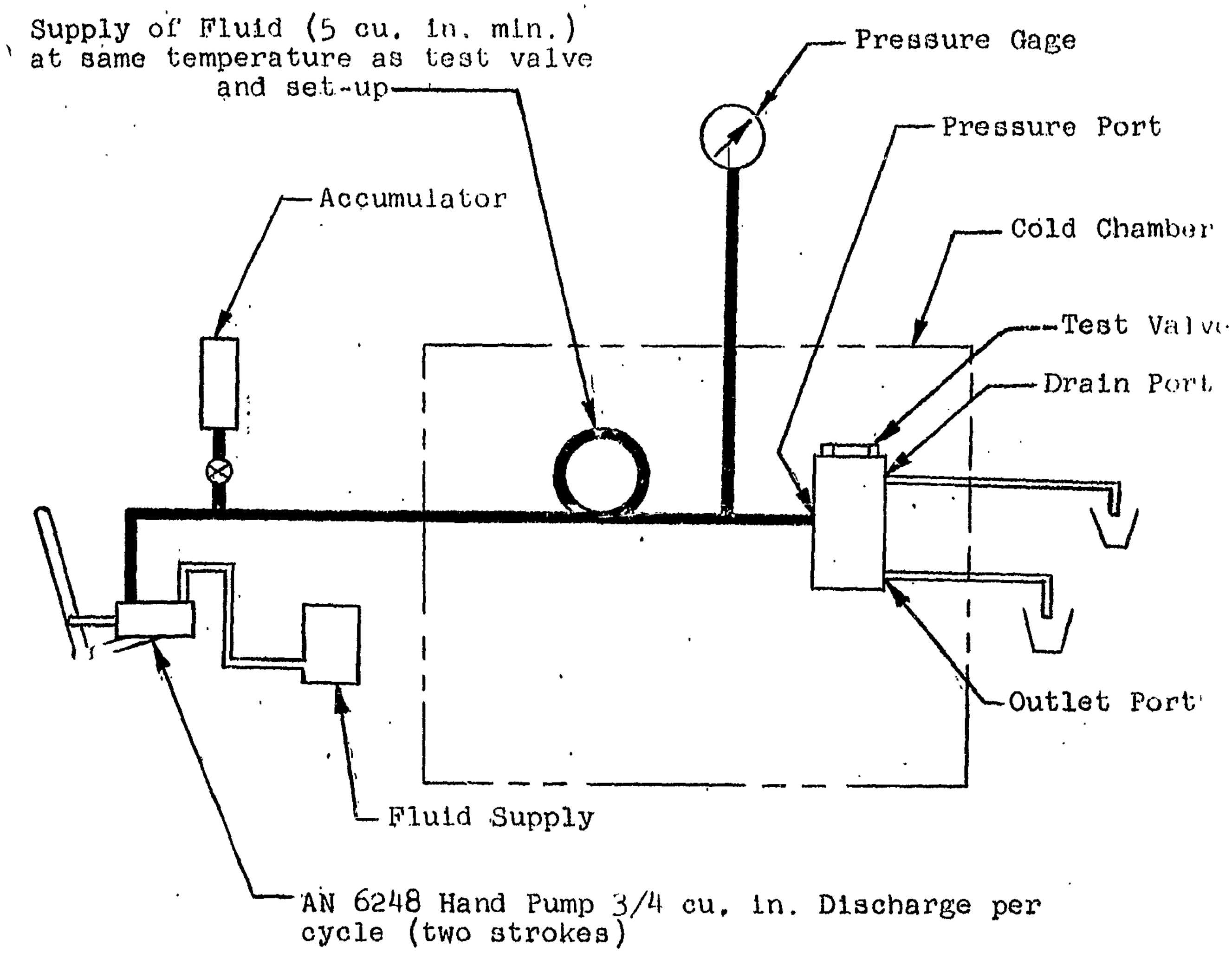


FIGURE 3

Typical Priority Valve Endurance Test Installation

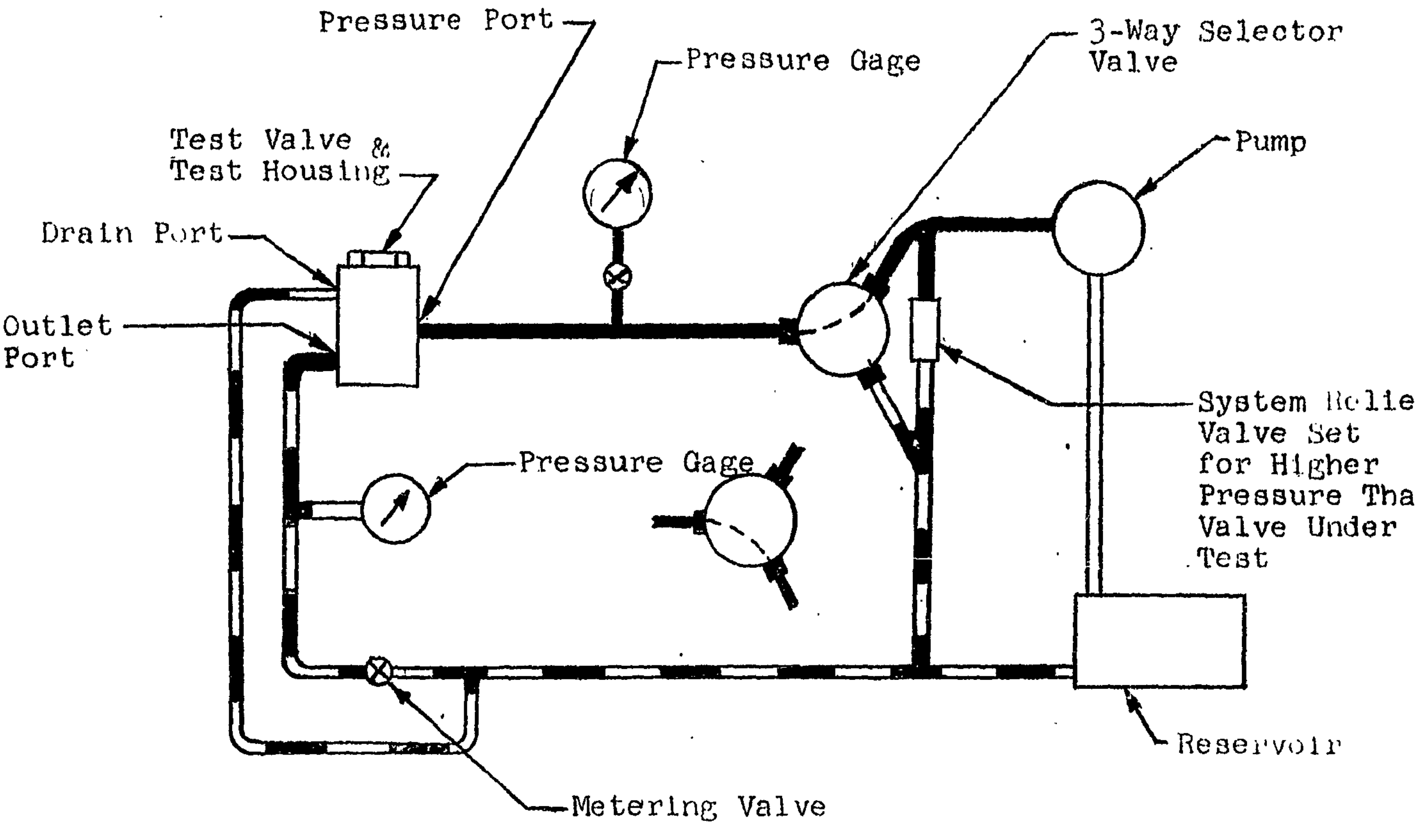
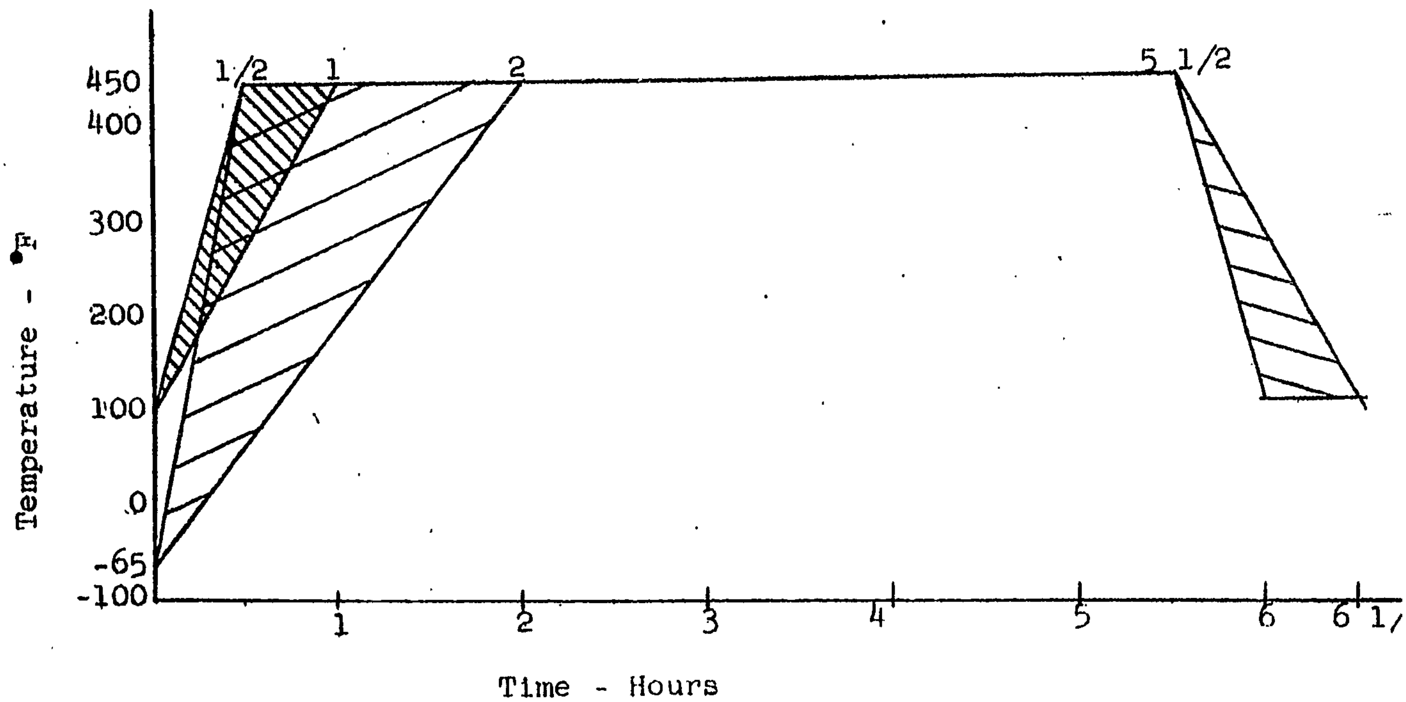


FIGURE 4

Time - Temperature Spectrum for Endurance Test



NOTES: 1. Rate of temperature rise or decay may vary within the shaded areas shown.

2. Approximately six and one half hours of endurance cycling are to be run in one day.

3. The ambient temperature shall be maintained between 450°F and 650°F during the time from the 2nd hour through 5 1/2 hours of the spectrum shown.

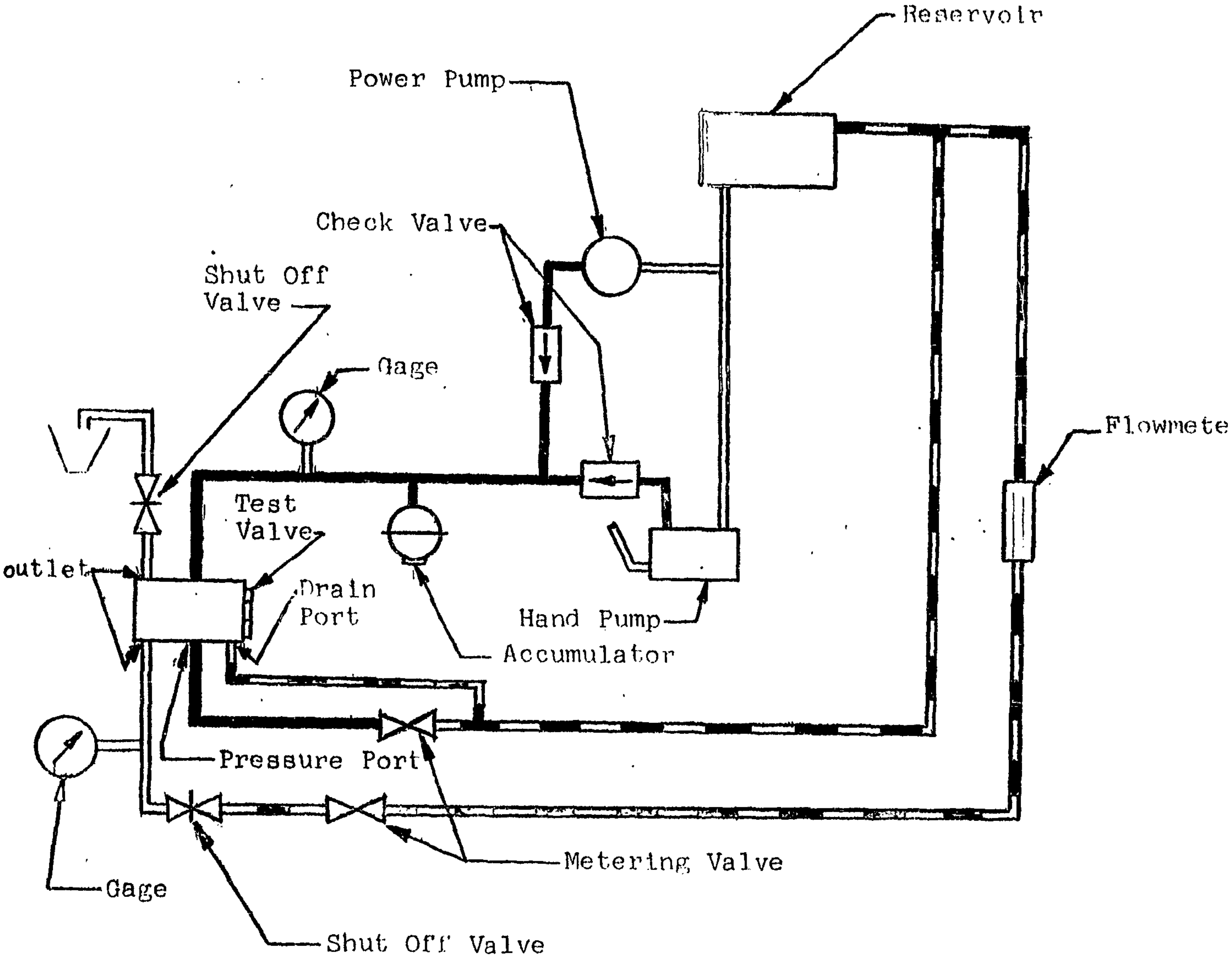
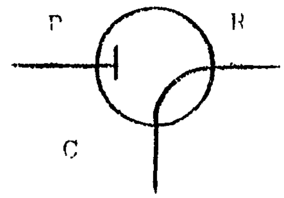


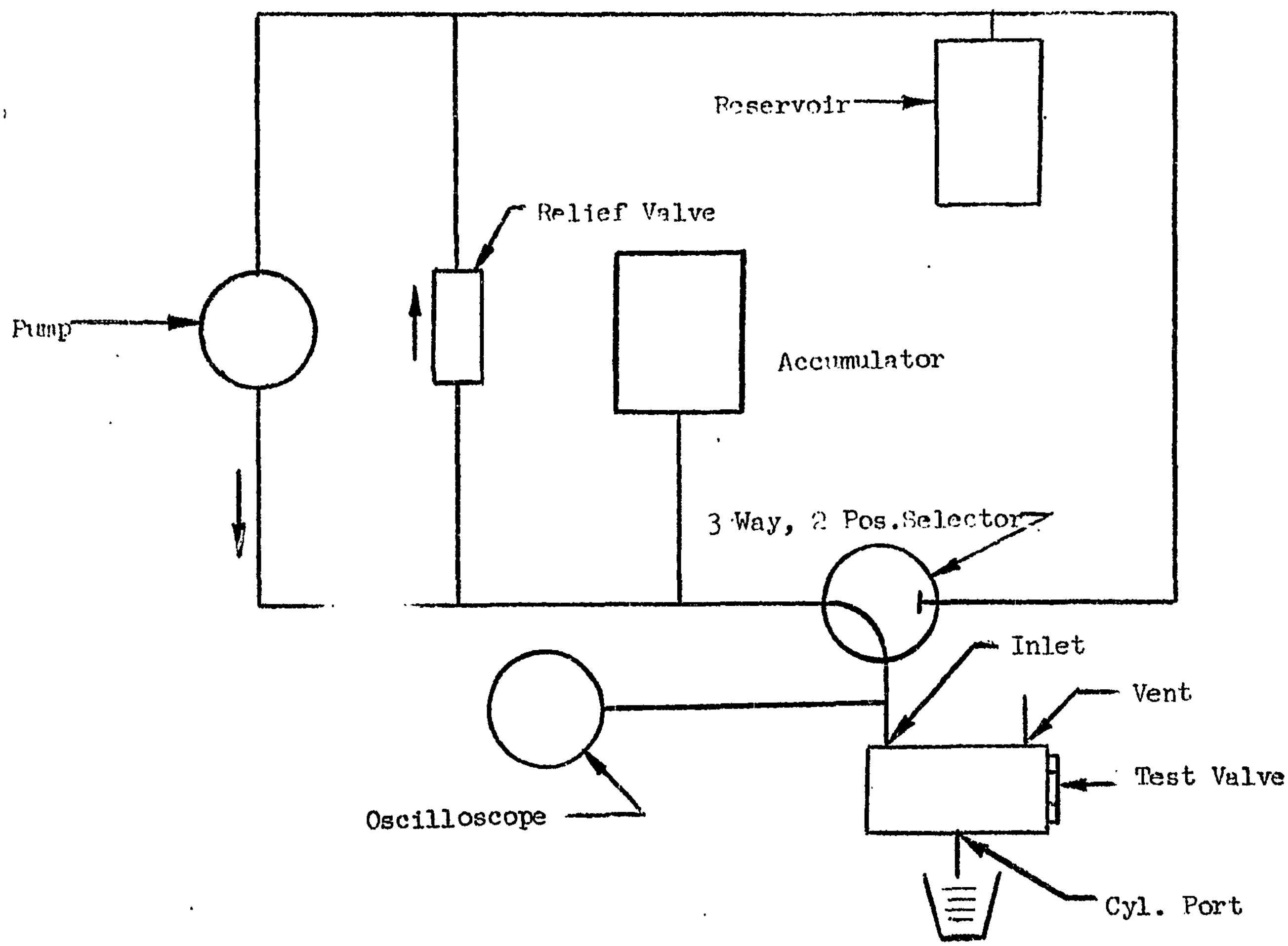
Figure 5. Typical Schematic for Normal Temperature Performance Test

FIGURE 6

TEST SET-UP FOR SURGE PRESSURE TEST

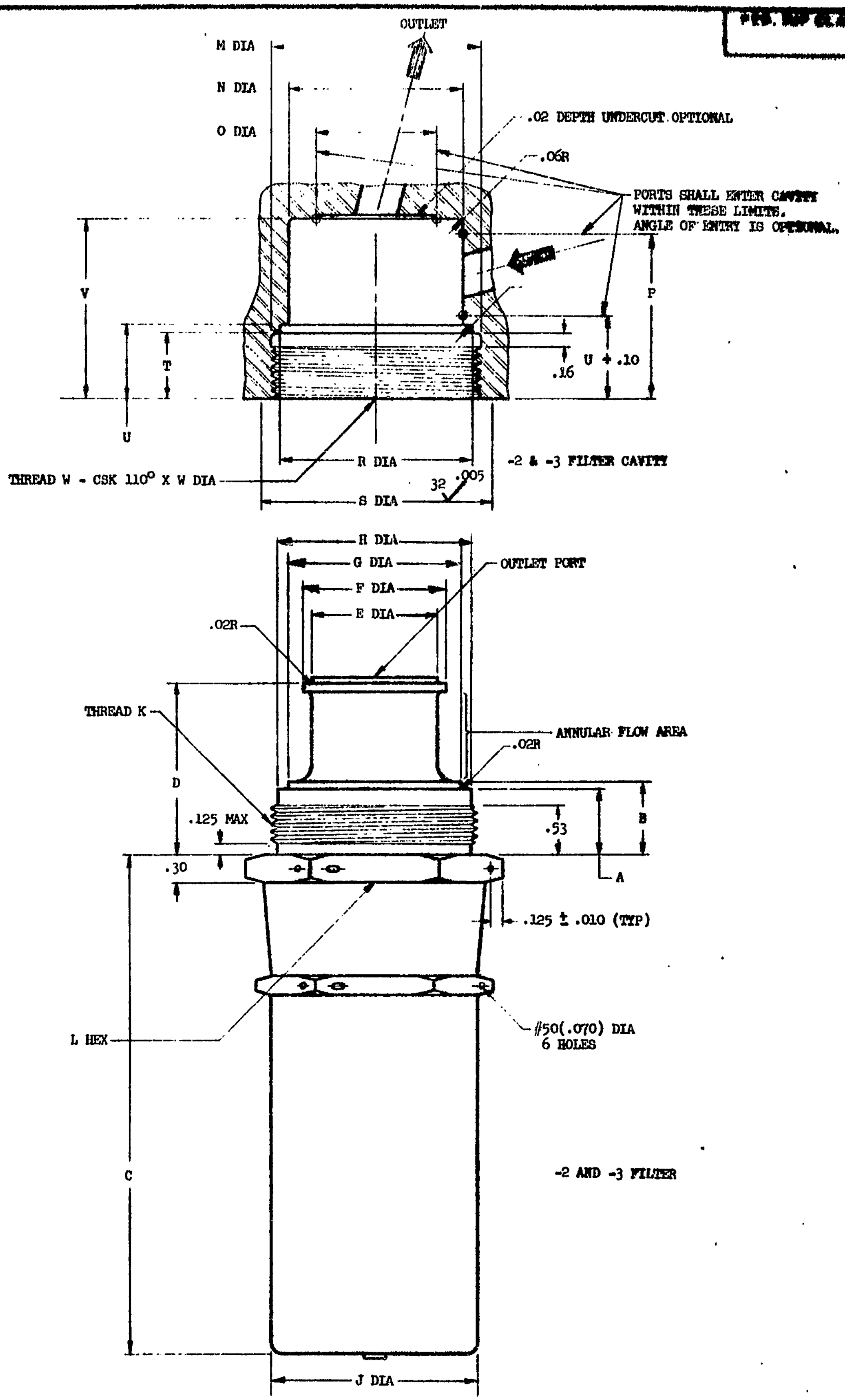


Alternate Position
of 3 way valve



APPENDIX XIII

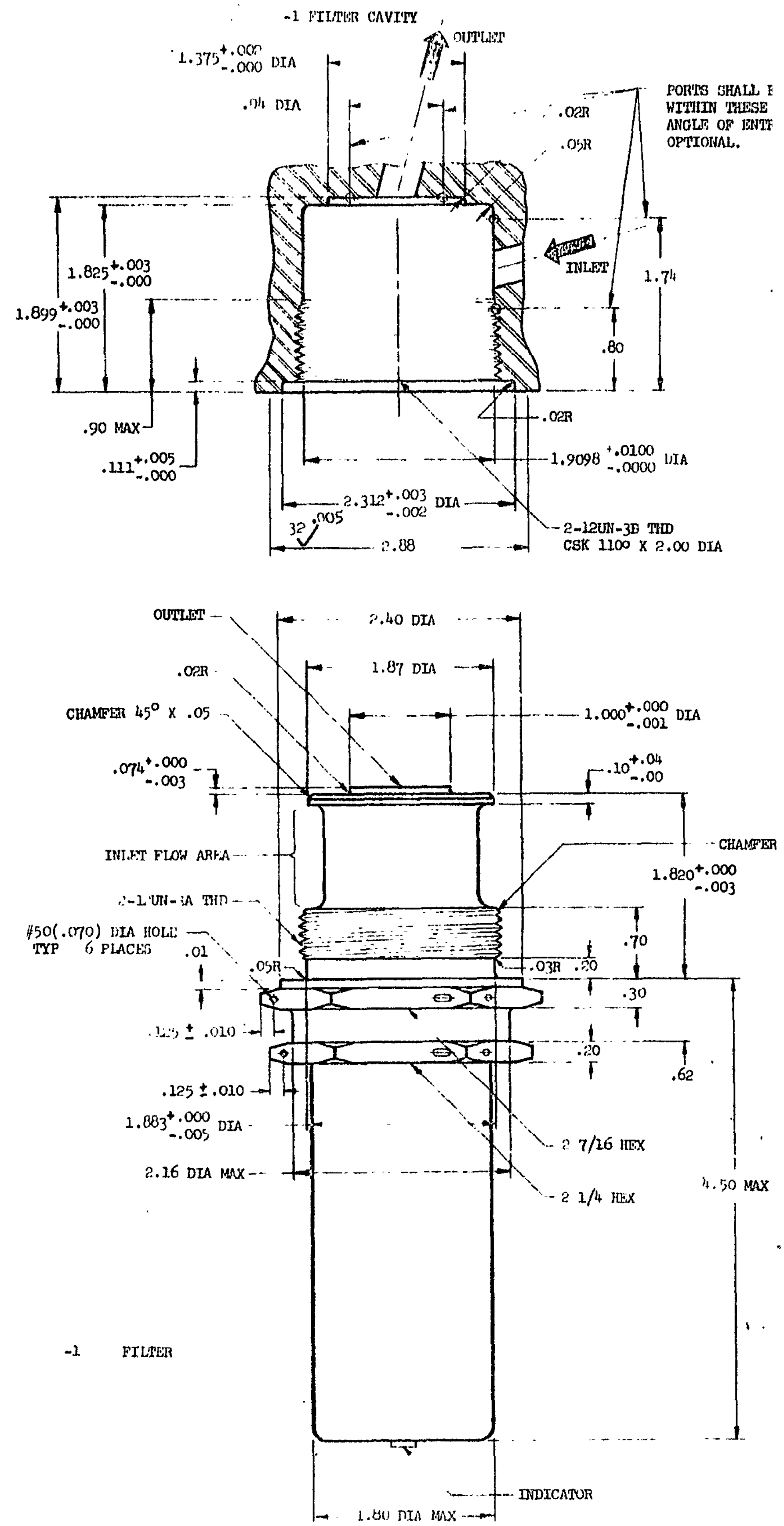
Suggested MIL Specification for Filter Assembly
Suggested MS Standard for Filter Assembly



P.A. Other Cust	TITLE **FILTER, 15 MICRON MODULAR HYDRAULIC** 4000 PSI TYPE III SYSTEM	**MILITARY STANDARD** **MS**
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 1 OF 3

REVISED

APPROVED



P.A.	TITLE	MILIT
Other Cust	**FILTER, 15 MICRON** **MODULAR HYDRAULIC** 4000 PSI TYPE III SYSTEM	MS
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 2

REVISED

APPROVED

FED. SUP CLASS

CAVITY DATA

CAVITY FOR PART NUMBER	THREAD W	M DIA +.005 -.000	N DIA +.010 -.000	O DIA	P	R DIA +.003 -.000	S DIA	T +.010 -.000	U +.003 -.000	V +.003 -.000
MS -1	NOTED									
MS -2	2 1/4-12UNF-3B	2.274	1.91	1.32	1.76	2.125	2.88	.70	.779	1.919
MS -3	2 5/8-12N-3A	2.649	2.25	1.40	2.12	2.500	3.22	.81	.911	2.280

FILTER DATA

PART NUMBER	THREAD K	A +.000 -.003	B	C MAX	D +.000 -.003	E +.000 -.002	F +.000 -.002	G MAX	H +.000 -.002	J MAX	L HEX	WEIGHT MAX	FLOW RATE GPM
MS -1	NOTED ←										→ NOTED	2.0	4
MS -2	2 1/4-12UNF-3A	.700	.78	5.34	1.840	1.875	1.745	1.90	2.120	2.25	2.437 +.000 -.050	3.0	12
MS -3	2 5/8-12N-3A	.800	.90	6.80	2.201	1.500	1.870	2.24	2.495	2.35	2.750 +.000 -.050	4.0	25

DETAIL REQUIREMENTS

MICRON RATING - 15 MICRON ABSOLUTE
TEMPERATURE LIMITS - 450°F FLUID AND 650°F AMBIENT MAXIMUM. FILTER SHALL FUNCTION AT -65°F
PRESSURE - OPERATING 4000 PSI, PROOF 6000 PSI, BURST 10,000 PSI
FLUID - SPECIFICATION MIL-H-8446
SEALS - SPECIFICATION MIL-
LIFE - SEE SPECIFICATION MIL- FOR ENDURANCE

MATERIAL: SEE SPECIFICATION MIL-
FINISH: SEE SPECIFICATION MIL-
MACHINE FINISHES: SEALING SURFACES (NOTED BY SYMBOL △) SHALL BE 16 RHR. ALL OTHER SURFACES SHALL BE 125 RHR.
TOLERANCES: THE SEALING SURFACES ON THE FILTER SHALL BE PARALLEL TO EACH OTHER WITHIN .002 FIR AND PERPENDICULAR TO THE FILTER THREAD WITHIN .003 FIR. THE SEALING SURFACES OF THE CAVITY SHALL BE PARALLEL TO EACH OTHER AND TO THE CAVITY BOSS WITHIN .002 FIR AND PERPENDICULAR TO THE CAVITY THREAD WITHIN .003 FIR.
LINEAR TOLERANCE: UNLESS OTHERWISE NOTED ±.01.
ANGULAR TOLERANCE: UNLESS OTHERWISE NOTED ±2°.
THIS FILTER IS INTENDED FOR INSTALLATION IN A MANIFOLD OR HOUSING FOR USE IN 4000 PSI TYPE III HYDRAULIC SYSTEMS WITHIN THE LIMITS SPECIFIED HEREIN AND BY SPECIFICATION MIL-
SEALING SURFACES ARE DENOTED BY THE SYMBOL ▲.
THREADS SHALL CONFORM TO SPECIFICATION MIL-S-7742.
THE APPLICABLE MS PART NUMBER, THE WORD "FILTER", THE RATED FLOW, AND THE MANUFACTURER'S NAME OR TRADEMARK SHALL BE PERMANENTLY MARKED ON THE FILTER ASSEMBLY IN A LOCATION SUCH THAT THE IDENTIFICATION IS VISIBLE WHEN THE FILTER IS INSTALLED.

REVISED

APPROVED

P.A. Other Cust	TITLE FILTER, 15 MICRON MODULAR HYDRAULIC 4000 PSI TYPE III SYSTEM	MILITARY STANDARD MS
PROCUREMENT SPECIFICATION	SUPERSEDES:	SHEET 3 OF 3

MILITARY SPECIFICATION

FILTER AND FILTER ELEMENTS; AIRCRAFT HYDRAULIC

1. SCOPE

1.1 Scope.- This specification covers cartridge-type modular hydraulic filter and filter elements, for use in Type III aircraft hydraulic systems conforming to Specification MIL-H-8891.

1.2 Classification.- Filter assemblies shall be of the following classes:

Class 1 - 0 to 4 gallons per minute flow rate

Class 2 - 0 to 12 gallons per minute flow rate

Class 3 - 0 to 25 gallons per minute flow rate

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified:

Specifications

Federal

PPP-T-60	Tape, Pressure Sensitive Adhesive, Waterproof

Military

MIL-B-121	Barrier Material, Greaseproof, Flexible, Waterproofed
MIL-I-6866	Inspection, Penetrant Method of
MIL-I-6868	Inspection Process, Magnetic-Particle
MIL-H-6875	Heat Treatment of Steels (Aircraft Practice) Process fo
MIL-S-7742	Screw Threads, Standard, Aeronautical
MIL-M-7911	Marking, Identification of Aeronautical Equipment, Assemblies and Parts
MIL-H-8446	Hydraulic Fluid, Nonpetroleum Base, Aircraft

MIL-H-8891	Hydraulic Systems, Type III Design, Installation, Tests and Data Requirements, General Specification For
MIL-D-70327	Drawings, Engineering and Associated Lists

Standards

MIL-STD-10	Surface Roughness, Waviness and Lay
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-143	Specification and Standards, Use of
MS-33540	Safety Wiring - General Practices for
MS-20995	Wire-Lock

Drawing

MS -	Filter Assemblies, Modular, Envelope for

2.2 Other publications.- Where it becomes necessary to use publications other than those listed in 2.1, they shall be selected in the order of precedence set forth in MIL-STD-143. Where contractor material and process specifications are permitted under MIL-STD-143, they shall contain provisions for adequate tests and inspection.

3. REQUIREMENTS

3.1 Qualification.- The filter assemblies furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed on, or approved for listing on, the applicable qualified products list.

3.2 Materials and processes.- Materials and processes used in the manufacture of these filter assemblies shall conform to the following requirements and to applicable specifications as defined in Section 2:

3.2.1 Metals.- All metals shall be compatible with the fluid and intended temperature, functional, service, and storage conditions to which the components will be exposed. The metals shall be of a corrosion-resisting type or shall be adequately protected to resist corrosion during normal service life of the filter assemblies which may result from such conditions as dissimilar metal combinations, moisture, salt spray and high temperature deterioration, as applicable. Copper, aluminum, and magnesium alloys shall be used only with the approval of the procuring activity. Ferrous alloys shall have a chromium content of not less than 12 percent or shall be suitably protected against corrosion. In addition, cadmium and zinc platings shall not be used for internal parts or on internal surfaces in contact with hydraulic fluid or exposed to its vapors.

3.2.2 Sub-zero stabilization of steel.- Close-fitting, sliding steel parts shall be cold stabilized in accordance with Specification MIL-H-6875 to reduce warpage tendencies.

3.2.3 Plastic parts.- Plastic parts shall be used only with the approval of the procuring agency for each application.

3.3 Parts.- Standard parts selected in accordance with Section 2 shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc., may be used, provided they possess suitable properties and are replaceable by approved standard parts without alteration and provided the approved standard part is referenced in the parts list and, if practicable, on the contractor's drawings.

3.4 Design and construction

3.4.1 Envelope.- The external configuration, dimensions, and other details of the design shall conform to the requirements of this specification, MS________ and applicable drawings.

3.4.2 Filter elements

3.4.2.1 Degree of filtration.- The filter element shall be capable of removing 100 percent of the particles over 15 microns and 90 percent of the particles under 15 microns in size by weight, when tested per 4.6.8 and 4.6.12.

3.4.2.2 Element patching.- When the element is of the type wherein resinous or any other material is used for elimination of imperfections, no more than five percent of the filtering area of the element shall be covered by the material. Filter element media having an initial bubble point of less than 3 inches of water before repair shall be unacceptable. When resin is employed for joining or patching, the application technique, curing cycle and procedures followed to insure adhesion of the resin shall be approved by the procuring activity.

3.4.2.3 Element collapse pressure.- The elements shall be capable of withstanding a differential pressure of 6,000 psi when tested per 4.6.11.

3.4.2.4 All filter elements shall be subjected to the bubble point test and shall meet the initial bubble point value established during qualification of the initial filter elements, when tested per 4.6.3.

3.4.3 Alignment.- All plungers, poppets, balls, pistons, etc., shall be guided to prevent misalignment or chattering on their seats.

3.4.4 Automatic shut-off.- The filter assemblies shall include a shut-off which will block all fluid passages when the filter sump and element are removed. The leakage rate through the shut-off shall not exceed the values specified in Table I, when tested per 4.6.5.

TABLE I

LEAKAGE RATE WITH FILTER SUMP AND
FILTER ELEMENT REMOVED

FILTER CLASS	PRESSURE PSI	LEAKAGE RATE MAX. DROPS/MIN.
1	50	8
	4,000	8
2	50	10
	4,000	10
3	50	12
	4,000	12

3.4.5 Hydraulic fluid.- The filter assemblies shall be designed for operation with hydraulic fluid conforming to Specification MIL-H-8446.

3.4.6 Temperature range.- The filter assemblies shall be designed to meet the functional and operational requirements of this specification throughout a fluid temperature range of -65°F to 450°F and an ambient temperature range of -65°F to 650°F. The filter assemblies shall be capable of withstanding 1,000 hours of operation at 450°F.

3.4.7 Threads.- Only class 3 threads conforming to Specification MIL-S-7742 shall be used.

3.4.8 Seals.- Seals shall be of metallic construction and shall be approved by the procuring agency.

3.4.9 Safetying.- Threaded parts shall be positively locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety wire shall be applied in accordance with Standard Drawings MS-33540 and MS-20995.

3.4.10 Retainer rings.- Except where they are Positively retained from being dislodged from their grooves, retainer or snap rings shall not be used in hydraulic equipment where failure of the ring will allow blow apart or jamming of the valve.

3.4.11 Structural strength.- The filter assemblies shall have sufficient strength to withstand all combinations of loads resulting from hydraulic pressure, temperature variations, and installation.

3.4.12 Weight.- The weight of the filter assemblies shall be kept to a minimum consistent with good design, and shall be as specified on the applicable drawing.

3.4.13 Mounting position.- The filter assemblies shall satisfy the performance requirements when mounted in any position.

3.4.14 Flow control.- The filter assemblies shall be of the full-flow type and shall be designed to pass rated flow per 1.2 from inlet port to outlet. Flow through the filter elements shall be from outside - in.

3.4.15 Surface roughness.- Surface roughness finishes shall be established and shall be specified on the manufacturer's assembly drawings as outlined in MIL-STD-10.

3.5 Interchangeability

3.5.1 Manufacturer's parts.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part

numbers shall be governed by the drawing number requirements of Specification MIL-D-70327. Subassemblies, composed of selected mating components, must be interchangeable as assembled units, and shall be so indicated on the manufacturer's drawings. The individual components, except filter elements, of such assembled units need not be interchangeable.

3.5.2 Maintainability.- Modular filter assemblies shall be self-contained components such that an assembly may be removed from one housing and inserted into another without any detail disassembly, readjustment, or impairment of function. The design of the filter assemblies sh ll be such that the elements may be removed for service and inspection without disconnecting fittings or disturbing mountings. The design shall be such that if the filter element is reversed, it shall be impossible to assemble the filter. Calculations shall be included as part of the test report indicating the maximum possible air inclusion, assuming the filter bowl is filled with fluid prior to assembly. The maximum calculated air inclusion shall not exceed 2 cc of free air.

3.6 Identification

3.6.1 Filter assemblies.- Each filter assembly shall have the identifying markings placed so that the identification can be read when the assembly is installed in a manifold cavity. Each assembly shall be permanently and legibly marked with the following information, per MIL-M-7911.

Filter, assembly
MS No.___________and direction of flow
Manufacturer's Part No.
Manufacturer's Name or Trademark

3.6.2 Filter element.- Each replaceable filter element shall have the following information permanently and legibly marked in a suitable place. The method of marking shall be such that the filter element shall meet the requirements of this specification.

MS No.
Manufacturer's Part No. and Serial
Manufacturer's Name or Trademark
Cleanable

3.7 Workmanship

3.7.1 Quality.- Workmanship shall be of sufficiently high quality to insure satisfactory operation and service life. The manufacturer shall exercise extreme care in fabricating, assembling, handling, and packaging filter assemblies to assure that the components are clean and free of contaminant. All parts shall be free from pits, rust, scrapes, splits, cracks, burrs, and sharp edges.

3.7.2 Physical defect inspection.- All magnetizable highly stressed parts shall be subjected to magnetic inspection in accordance with Specification MIL-I-6868. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection. All non-magnetizable highly stressed parts shall be subjected to fluorescent penetrant inspection in accordance with Specification MIL-I-6866. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

3.8 Performance

3.8.1 Operating pressure.- The filter assemblies shall be designed to insure satisfactory operation and service life throughout the pressure range from 0 to 4,000 psi, when tested per 4.6.7. The assemblies shall be capable of operation at pressures to 6,000 psi.

3.8.2 Proof pressure.- The filter assemblies shall be designed to withstand a proof pressure of 6,000 psi, when tested per 4.6.2, and there shall be no evidence of external leakage permanent set or other damage.

3.8.3 Burst pressure.- The filter assemblies shall be designed so as not to burst at any pressure below 10,000 psi, when tested per 4.6.15.

3.8.4 Pressure drop.- The pressure drop of the filter assemblies, without the elements, shall not exceed 15 psi at rated flow, when tested per 4.6.4. A free-flow dummy element shall be installed to hold open the automatic shut-off.

3.8.5 Differential pressure indicator.- Filter assemblies shall incorporate an integral, non-electrical, pressure warning device.

3.8.5.1 Actuation.- When the differential pressure across the element exceeds 80±10 psi, a noticeable, red indicator shall raise or extend from the assembly. The indicator shall remain in view, once actuated, until manually reset, when tested per 4.6.6 and 4.6.7.

3.8.5.2 Reset position.- The indicator shall be hidden from view in the reset position and shall not be operable below 30°F±20°F, when tested per 4.6.6.

3.8.5.3 The indicator shall be capable of 1,000 cycles of repetitive operation, when tested per 4.6.7.

3.8.6 Filter element bubble point value.- The initial bubble point value shall be established by the activity responsible for qualification. The bubble point value shall be the lowest initial bubble point of the elements, when tested per 4.6.3. Filter elements submitted for acceptance test shall equal or exceed the established bubble point value or be rejected, when tested per 4.6.3. The bubble point of an element shall not be reduced as a result of performing any of the qualification tests except the collapse pressure test.

3.8.7 Impulse cycling.- Filter assemblies shall be designed to withstand 100,000 impulse cycles, when tested per 4.6.9 and there shall be no evidence of external leakage or structural failure.

3.8.8 Flow fatigue.- With the filter element loaded with AC fine test dust, the filter assembly shall be capable of withstanding 100,000 pressure - flow cycles without damage, when tested per 4.6.10.

3.8.9 Vibration.- The filter assemblies shall be capable of withstanding vibrations from 50 to 500 cps at 10 g's in each of the three mutually perpendicular planes, when tested per 4.6.14.

3.8.10 Cold start.- The filter assemblies shall be capable of satisfactory operation with hydraulic fluid at a minimum viscosity of 2200 centistokes, when tested per 4.6.13.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.- Unless otherwise specified herein, the manufacturer is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 Classification of tests.- The inspection and testing of filter assemblies shall be classified as follows:

(a) Qualification tests
(b) Acceptance tests

4.3 Qualification tests

4.3.1 Sampling instructions

4.3.1.1 Filter assemblies.- Samples of filter assemblies for qualification tests shall consist of one specimen of each class of filter assembly upon which qualification is desired.

4.3.1.2 Filter elements.- Three filter elements of each class shall be selected for qualification tests. The number three element of each set shall be the element having the lowest initial bubble point value and the number two element of each class set shall be the element having the highest initial bubble point value. The remaining element shall be the number one element. One of the three elements shall be the element included in the filter assembly sample of paragraph 4.3.1.1.

4.3.1.3 The specimens shall be assembled of parts which conform to manufacturer's drawings.

4.3.1.4 The manufacturer shall provide calculations showing that adequate clearance of moving parts is provided at -65°F and 450°F using the most adverse dimensions. The room temperature reference point shall be 70°F.

4.3.2 Tests.- The qualification tests shall consist of the following tests which shall be conducted in the order listed.

(a) Examination of product per 4.6.1.

(b) Bubble point per 4.6.3.

(c) Proof pressure per 4.6.2.

(d) Pressure drop per 4.6.4.

(e) Extreme temperature performance per 4.6.6.

(f) Differential pressure indicator operation per 4.6.7.

(g) Automatic shut-off leakage per 4.6.5.

(h) Degree of filtration per 4.6.8.

(i) Impulse per 4.6.9.

(j) Flow fatigue per 4.6.10.

(k) Pressure build-up and collapse per 4.6.11.

(l) Largest particle passed per 4.6.12.

(m) Cold start test per 4.6.13.

(n) Media migration and vibration 4.6.14.

(o) Burst pressure 4.6.15.

4.4 Acceptance tests.- Acceptance tests shall be performed on individual filter assemblies or lots which have been submitted under contract to determine conformance of the assemblies or lots with requirements set forth in this specification prior to acceptance. Each filter assembly shall be subjected to the following tests:

(a) Examination of product per 4.6.1.

(b) Bubble point per 4.6.3.

(c) Proof pressure per 4.6.2.

(d) Differential pressure indicator operation per 4.6.7.

(e) Pressure drop per 4.6.4.

(f) Automatic shut-off leakage per 4.6.5.

4.5 Test conditions

4.5.1 Test fluid.- The test fluid shall conform to Specification MIL-H-8446.

4.5.2 Fluid temperature.- If the fluid temperature is not otherwise specified for a given test, it shall be 95±15°F for that particular test. The outlet fluid temperature shall be specified, and the inlet fluid temperature

may be reduced to compensate for heat generation. The fluid temperature shall be measured as near as practicable to the filter assembly ports. During all soaking periods, the component shall be bled of air and inert gas and maintained full of fluid.

4.5.3 Test housing

4.5.3.1 Qualification test housing.- All tests in 4.3.2 shall be conducted in a thin wall test housing which is contoured externally to follow the cavity and which is acceptable to the procuring agency.

4.5.3.2 Acceptance test housing.- The tests in 4.4 may be conducted in the qualification test housing or in a housing having other external configuration.

4.6 Test methods

4.6.1 Examination of product.- The filter assembly and elements shall be carefully examined to determine conformance with the requirements of this specification for weight, workmanship, marking, envelope, defects and conformance of dimensions of detail parts to the manufacturer's drawings. The determination of surface finish shall be made with a profilometer, comparator brush analyzer, or equally suitable comparison equipment with an accuracy of ±5 micro-inches at the level being measured.

4.6.2 Proof pressure test.- With the outlet port of the filter assembly plugged, pressure shall be applied to the inlet port at the rate not exceeding 25,000 psi per minute until 6000 psi is reached. This proof pressure shall be held for at least two minutes. There shall be no external leakage, permanent set, or other damage. For qualification, the components and the fluid shall be stabilized at a temperature of 450°F±15°F. Acceptance test temperature shall be 95°F±15°F.

4.6.3 Bubble point test.- The test element containing no oil is installed in a set-up similar to that shown in Figure 1. Fluid level is to be maintained 1/2" above the top of the test element. The air pressure within the element is raised in small increments and the element is slowly rotated 360° at each pressure increment. The area of greatest porosity is determined by observing the first bubble on the surface of the element, and the manometer reading in inches of water at which this bubble emits from the surface of the element is recorded. This is the initial bubble point. The initial bubble point for all elements shall be determined and recorded. The fluid used shall be Solox 190 or equivalent. The bubble test shall be accomplished within a period of 10 minutes. The fluid temperature shall be 95 ± 15°F for this test. The lowest recorded initial bubble point shall be the value for acceptance testing filter elements. No element submitted to acceptance bubble tests shall be higher than this value.

4.6.4 Pressure drop test (using a free-flow dummy element).- With rated flow (Ref. paragraph 1.2) through the filter assembly the pressure drop shall not exceed 15 psi. The fluid temperature shall be 95±15°F for this test.

4.6.5 Automatic shut-off leakage test.- Fifty (50) psi shall be applied to the inlet and the outlet ports of the filter test housing, simultaneously. The filter sump and filter element shall be removed and the leakage recorded. The pressure shall be held for a 5 minute period and the leakage measured during the last 3 minutes of the 5 minute period. The procedure shall be repeated 5 times, and the rate of external leakage shall not exceed the values specified in Table I. With the sump and element removed from the assembly, 4 000 psi shall be applied to the inlet and the outlet passages for a 5 minute period with the leakage measuring period consisting of the last 3 minutes. The rate of leakage shall not exceed the values specified in Table I.

4.6.6 Extreme temperature performance test (using a dummy element).- The filter assembly shall be soaked at a temperature not warmer than -65°F for 8 hours. At the end of this period, a pressure of 90 psi shall be applied to the inlet port of the unit and held for 10 minutes, with the outlet port vented to atmosphere. The differential pressure indicator shall not actuate. Proof pressure, 6000 psi, shall be applied to the inlet port and the indicator shall not actuate. A pressure of 90 psi shall be applied to the unit with the outlet port vented to atmosphere. The temperature of the fluid shall be warmed up rapidly and the temperature at which the differential pressure indicator actuates shall be measured and shall be 30±20°F. The pressure shall then be reduced to zero while the temperature is increased to 450±15 °F. The pressure shall then be slowly increased until the indicator actuates and this indicator operating pressure shall be within the range of 80±10 psi.

4.6.7 Differential pressure indicator operation test (using a dummy element).

4.6.7.1 Low system pressure.- With the element port plugged and the outlet port vented to atmosphere, increase the pressure at a rate of 20 psi per minute at the inlet port of the filter until the pressure indicator actuates fully, This shall be considered the indicator operating pressure, and shall occur at 80±10 psi. The inlet pressure shall then be reduced to zero and the indicator manually reset. The pressure shall then be cycled 1000 times at any practical rate from 0 to 90 psi and back to 0 psi. The indicator shall require and shall be reset at the end of each cycle. The indicator operating pressure shall be checked following cycling and shall occur at 80±10 psi.

4.6.7.2 High system pressure.- The element port shall be blocked with a plug containing an orifice designed to provide rated flow at 90 psi differential pressure across the orifice. The outlet port of the filter shall be throttled to provide rated flow at 4000 psi inlet pressure. The flow shall be cycled from zero to rated flow and the differential pressure at which the indicator fully actuates shall be noted. This shall occur at a differential pressure of 80±10 psi. The inlet pressure shall then be raised to 4000 psi and dropped to 0 psi. The indicator shall remain in the "up" position throughout the pressure range of 0 to 4000 psi. The indicator shall then be manually reset. This cycle shall be repeated 1000 times. The differential pressure indicator operating pressure at 4000 psi inlet pressure shall then be rechecked and shall occur at 80±10 psi.

4.6.7.3 Differential pressure indicator acceptance test.- By using a hand pump, slowly increase the pressure at the inlet port of the filter assembly until the pressure indicator actuates fully and locks. This shall be the indicator operating pressure and shall occur at 80±10 psi. Reduce pressure to 0 psi. At 0 psi, the indicator shall remain locked in the "UP" position. The differential pressure shall then be raised to 4500 psi and dropped to 0 psi. The indicator shall remain in the locked "UP" position throughout the pressure range from 0 psi to 4500 psi to 0 psi. The flag shall then be manually reset. The fluid temperature shall be 95±15°F for this test.

4.6.8 Degree of filtration.- It is of primary importance that the hydraulic fluid and air used in the degree of filtration test be clean and filtered prior to test. Figure 2 shows a degree of filtration test set-up with a clean-up device attached.

4.6.8.1 Test procedure for determination of oil cleanliness

A. The clean-up apparatus consisting of needle valve, millipore holder, millipore disc (Type HA, 1" diameter) manometer, flowmeter and low flow pump with adjustable internal by-pass shall be installed on the test stand similar to the set-up shown in Figure 2.

B. A constant flow with at least periodic agitation of the contaminant mixing chamber, at a minimum pressure differential of 100 psi across the millipore filter assembly shall be established and maintained for 30 minutes.

C. The pressure drop across the millipore fixture shall be recorded at the beginning and end of the flow period.

D. The variation in pressure drop as recorded shall not exceed 5% of the initial value. If the variation exceeds 5% the system shall be recleaned.

4.6.8.2 Filter elements.- Degree of filtration for filter elements shall be determined as shown in the following procedure:

A. A set-up shall be made as shown in Figure 2 without the filter elements installed in the test housing.

B. 2000 ml of pre-filtered hydraulic fluid shall be flushed through the contaminant mixing chamber and the filter housing and discarded. Repeat this operation.

C. 2000 ml of previously filtered hydraulic fluid shall be added through the plug valve "A". Element number 1 shall be installed in the filter housing.

D. The fluid shall be checked in accordance with 4.6.8.1.

E. Valve "B" shall be closed.

F. A 5 ml slurry containing 0.32, 0.75, and 1.30 for the class 1, 2, and 3 filter assemblies, respectively, shall be added to the fluid through a small funnel inserted in the plug valve "A". The contaminant shall be A/P.M. F-9 beads (See Figure 5).

G. The contaminant shall be uniformly distributed by churning the hydraulic fluid for 5 minutes with an agitator.

H. Plug valve "A" shall be closed and the glass chamber containing hydraulic fluid and contaminant shall be pressurized by the air regulator. The air regulator is used to maintain flow. Sufficient air pressure shall be employed to maintain rated flow.

I. Gate valve "B" shall be opened and air pressure shall force fluid containing contaminant through sample filter assembly. This filtrate shall be collected in a 5000 ml beaker. 2000 ml of petroleum ether (B.P. 95 - 130°F) shall then be washed through the contaminant mixing chamber and test filter assembly using a suitable wash bottle. The wash fluid shall be collected in the same 5000 ml beaker.

J. A millipore filter paper disc (Type AA-047) shall be washed with 200 ml of petroleum ether and dried to constant weight at 125°F. The weights shall be accurate to 0.1 mg.

K. The weighed filter paper is assembled into filter holder assembly (see Figure 4) and fitted to a 5000 ml vacuum flask connected to a suitable vacuum pump (min 25" of Hg vacuum).

L. All fluid passed through the test filter is filtered through the millipore disc. 500 cc of petroleum ether (B.P. 95 - 130°F) previously filtered in the above manner is used to wash the millipore disc.

M. Maintaining vacuum, the top half of filter funnel assembly is removed. The filter paper is now exposed for further washing.

N. With a wash bottle of filtered petroleum ether (B.P. 95 - 130°F) the rim of the filter paper is gently washed to remove the traces of oil being careful not to disturb the cake. Vacuum must be maintained during the above operation.

O. The vacuum is shut off and the filter paper removed. It is dried to a constant weight at 125°F and weighed to a tenth of a milligram. The difference between the filter paper weight before and after the above procedure is the weight of contaminant passing through the test filter, B in formula below. The above test, with the element removed, shall be repeated 4 times for 4 separate contaminant add values (A in formula below). Oil cleaned to a level that conforms with 4.6.8.1 shall be used for each test. The contaminant collected shall be the add value and shall be used in the calculation of degree of efficiency. It shall be the average of these 4 runs. A system blank value shall be obtained by repeating steps A through O above with the filter element installed and no contaminant added. This blank value shall be the value C in the efficiency formula below:

$$\% \text{ removal} = \frac{A - (B-C)}{A} \times 100$$

No one of the 4 add values shall be less than 95% by weight of the contaminant introduced.

P. The filter assembly shall remove 92% by weight of the contaminant add value. This is equivalent to 100% removal of particles over 15 microns and 90% removal of particles under 15 microns in size by weight.

4.6.9 Impulse.- Filter assembly (using element number 1) shall be subjected to 100,000 impulse cycles at 450±15°F. Each impulse cycle shall consist of a pressure rise from 0 to 4000 psi and a drop to 0. During each pressure increase, a peak surge pressure of 1.43 to 1.57 times 4000 psi, as shown by an oscilliscope, shall be obtained. The impulse time (duration of impulse) shall be no longer than .05 seconds and the rate of pressure rise shall be a minimum of 50,000 psi per second. Cycling shall be performed at a maximum rate of 300 cycles per minute. There shall be no evidence of external leakage or structural failure during the performance of this test. The differential pressure indicator shall not actuate during the impulse test.

4.6.10 Flow fatigue.- Filter element (using element number 2) shall be installed in the housing and subjected to pressure-flow cycles with fluid at 450±15°F. A cycle shall consist of increasing the differential pressure across the element from 0 to the maximum specified and back to 0 by first increasing then decreasing the flow through the test element which has been loaded with AC fine test dust. The cycling rate shall not exceed 300 cycles per minute. The number of cycles at each differential pressure shall be as follows:

Series I - 90,000 cycles at 20 psi drop
Series II - 8,000 cycles at 50 psi drop
Series III - 1,900 cycles at 100 psi drop
Series IV - 100 cycles at 4000 psi drop

There shall be no evidence of damage as a result of this test.

4.6.11 Pressure build-up and collapse pressure test.

A. The test fluid used in the system shown on Figure 3 shall be precleaned by flowing through a clean-up filter using the test procedure outline in paragraph 4.6.8.1. A clean-up filter shall be used throughout this test unless otherwise noted.

B. Element number 2 shall be installed in the filter assembly.

C. The pump shall be started, valves A and B opened, and rated flow attained by adjusting the vari-drive.

D. Standardized fine air cleaner test dust shall be added through the dust valve H in the following increments at 2 minute intervals: .09, .19 and .32 grams, in slurry, for Class 1, 2, and 3 filter assemblies, respectively. This test dust shall have the following composition:

Size of Particle	Percent by Weight of Total
0 to 5 microns	39 ± 2
5 to 10 microns	18 ± 3
10 to 20 microns	16 ± 3
20 to 40 microns	18 ± 3
Over 40 microns	9 ± 3

E. After each dust addition, pressure differential, flow and temperature shall be recorded. Dust shall be added until the maximum weight of dust is added for each. These shall be 0.48, 1.12, and 1.96 grams for class 1,2 and 3 filter assemblies, respectively. The differential pressure across the filter assembly shall not exceed 90 psi. The pump shall not be stopped during the test. Additional dust shall be added until a differential pressure of 4000 psi is obtained across the element at rated flow. The dirt capacity to 4000 psi shall be noted and recorded.

F. Elements shall be loaded 10 times to 4000 psi and cleaned 10 times. After the final cleaning, the dirt capacity to 4000 psi shall not be less than 90% of the original dirt capacity to 4000 psi. Elements shall be cleaned in accordance with recommendations to be submitted by the manufacturer.

G. As the fluid is being circulated at rated flow the temperature shall be raised to 450°F and the collapse pressure of the element shall be determined by adding additional quantities of AC Dust to the test system. The collapse pressure of the element shall be more than 6000 psi.

4.6.12 Largest particle passed using element number 3.

A. A degree of filtration test shall be conducted in accordance with the procedure outlined in subparagraphs A, B, C, D, and E of 4.6.8.2 with 2000 ml of hydraulic fluid and 0.05 grams of APM F-9 glass beads.

B. The effluent shall be passed through a disc of AA millipore filter paper.

C. The entire disc shall be scanned. The largest bead shall be no greater than 15 microns in size.

4.6.13 Cold start test using element number 3. Element shall be loaded with dirt in accordance with paragraph 4.6.11 until the differential pressure across the element reaches 90 psi. The element shall then be subjected to a total of 10 flow cycles at 150% of rated flow using hydraulic fluid with a minimum viscosity of 2200 centistokes, except that the flow rate shall not exceed that necessary to obtain a differential pressure of 4000 psi across the element. Each cycle shall have a minimum duration of 10 seconds. While flowing fluid at 90 to 100°F, additional dust shall be added until a differential pressure of 4000 psi is obtained across the element and the total amount of dust added shall be noted.

The dirt capacity to 4000 psi shall be a minimum of 90% of the dirt capacity to 4000 psi recorded in 4.6.11.

4.6.14 Media migration and vibration.- The test filter assembly (using element number 3) shall be mounted on a suitable test stand and the oil in the test system shall be precleaned using the test procedure outlined in 4.6.8.1. The filter assembly filled to the top of the element with a suitable fluid shall be maintained at 450 ± 15°F for 72 hours before vibrating. The assembly shall be cooled to room temperature (70 - 90°F) and vibrated at room temperature in three mutually perpendicular planes. The frequency of vibration shall be varied from 50 to 500 cps, with one pass of scanning to be at least 15 minutes, at an acceleration of 10g's in each plane with any resonant frequencies noted. The filter assembly shall be vibrated for one hour at each of these resonant frequencies. If no resonance is encountered, the vibration frequency shall be 500 cps for one hour at an acceleration of 10 g's in each plane. The differential pressure indicator shall not actuate during this test. At the completion of the vibration period and with the test pumping system and valves preset to give rated flow through the filter, the system shall be started and 1 gallon of fluid passed through the filter and effluent collected. The sample effluent shall be completely filtered through AA millipore paper (47 mm disc) and the amount collected and scanned under a microscope. There shall be no migration traceable to the element or its packaging.

4.6.15 Burst pressure.- Using element number 3 and with the outlet port plugged, pressure shall be applied to the inlet port at a rate not to exceed 25,00 psi per minute until 10,000 psi is reached. Filter assemblies shall show no signs of rupture of external or internal parts when this pressure is held for 2 minutes. The fluid temperature shall be 95 ± 15°F for this test.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging.- Each filter assembly shall be filled with hydraulic fluid conforming to MIL-H-8446. All internal surfaces of components shall be completely coated with fluid and then drained to the drip-point prior to sealing. The component or assembly shall then be wrapped or bagged in grade A greaseproof paper conforming to Specification MIL-B-121 and sealed with tape conforming to Specification PPP-T-60. Each wrapped component or assembly shall be packaged in accordance with the manufacturer's commercial practices.

5.2 Marking of shipments.- Interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and shall include the following:

Stock No. as specified in the purchase document
Name of part
MS part No.
Month and year of manufacture
Class or size

6. NOTES

6.1 Intended use.- The filter assemblies covered by this specification are intended for use in 4,000 psi nominal aircraft and missile hydraulic systems covered by Specification MIL-H-8891, and operating with hydraulic fluid conforming to Specification MIL-H-8446. The filter assembly is further intended for use in a manifolded or packaged type system.

6.2 Ordering data.- Procurement documents should specify the following:

(a) Title, number and date of this specification.

(b) MS part number.

(c) Class

(d) Federal stock number.

6.3 Qualification.- With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D. C.; however, information pertaining to qualification of products may be obtained for the Commanding Officer, U. S. Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

Custodians:

Navy - Bureau of Naval Weapons
Air Force

Preparing Activity:

Navy - Bureau of Naval Weapons

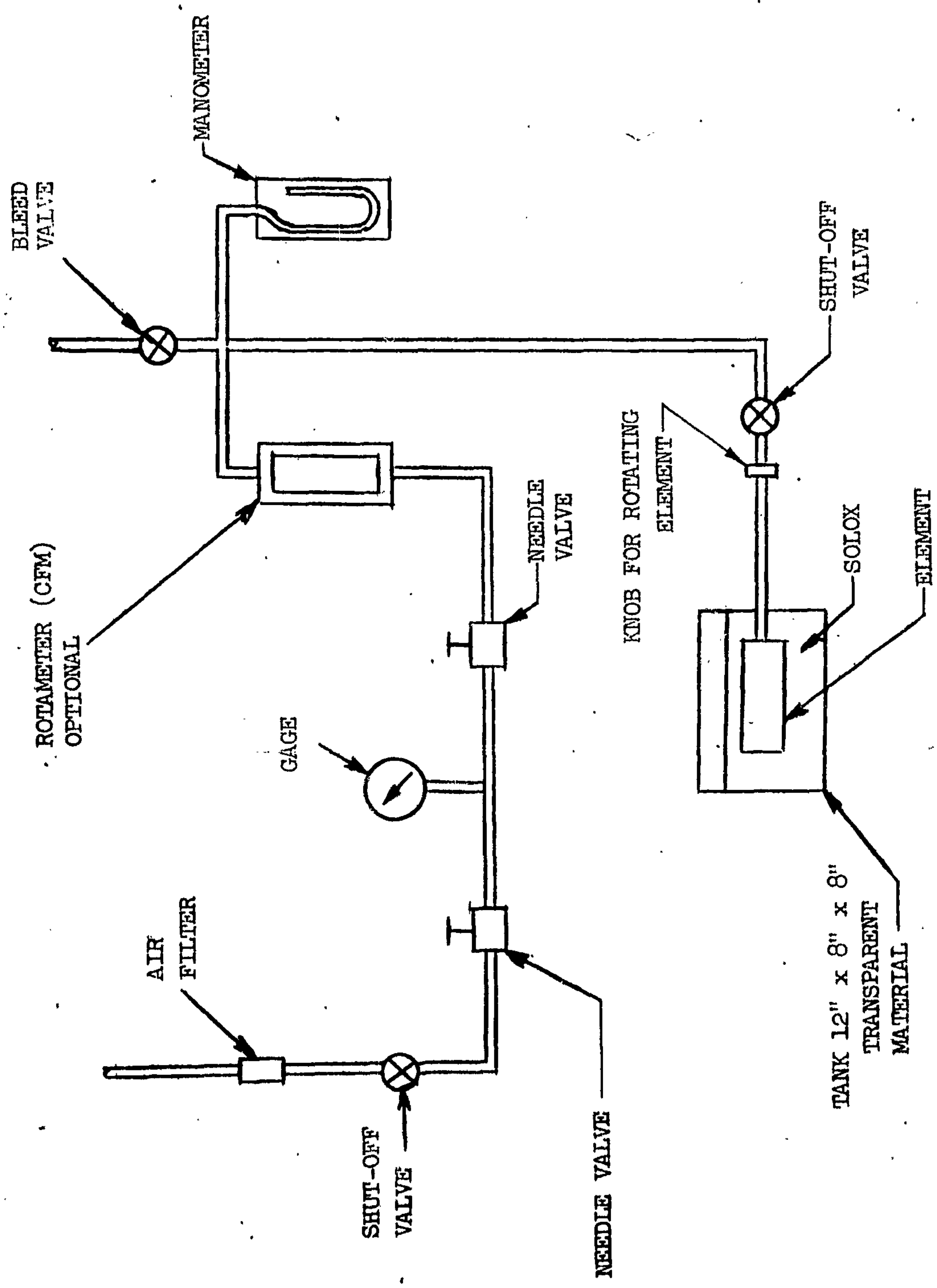


FIGURE 1

TYPICAL SCHEMATIC FOR AIR BUBBLE TEST

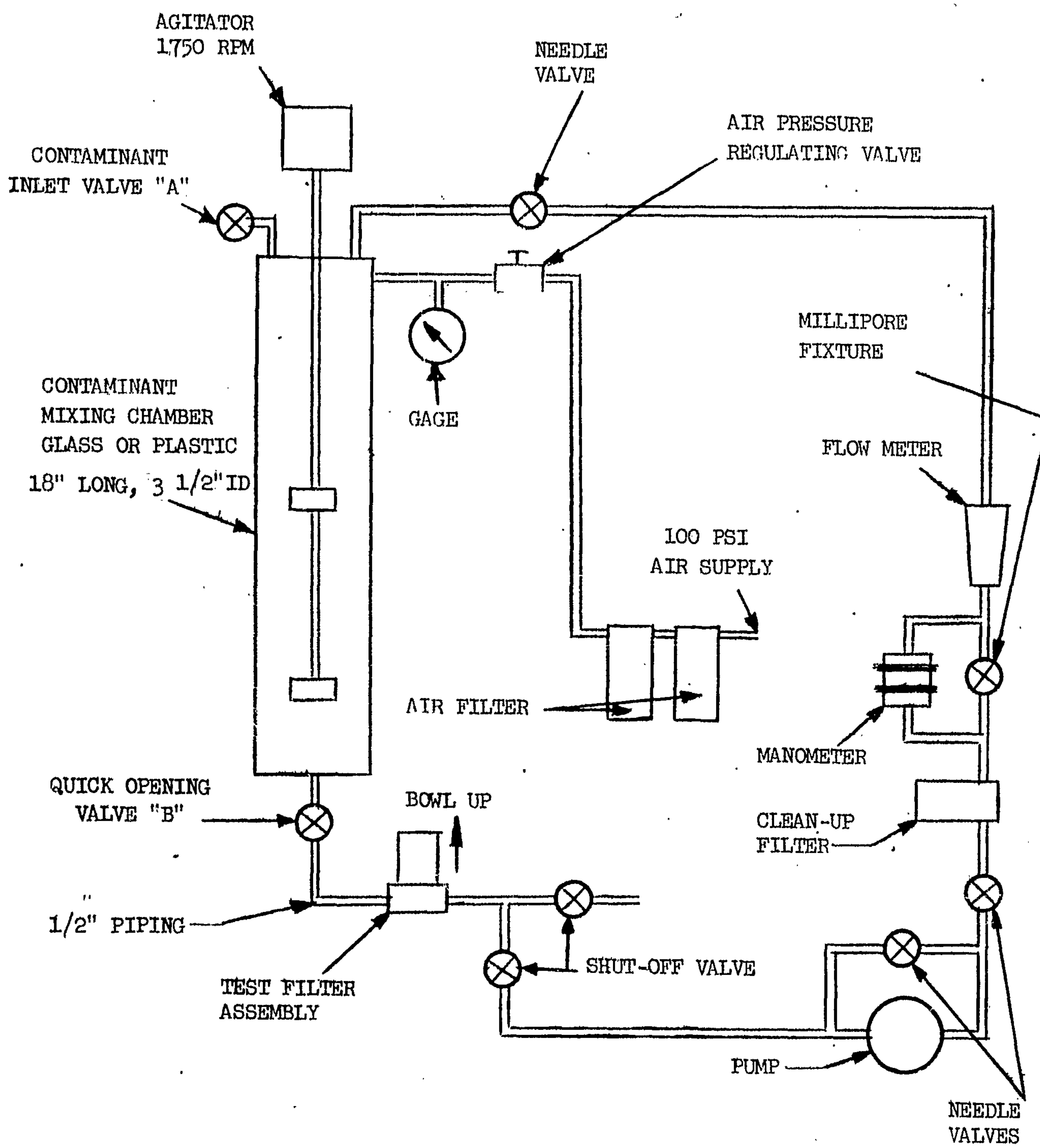


FIGURE 2

TYPICAL SCHEMATIC FOR FILTRATION EFFICIENCY DETERMINATION

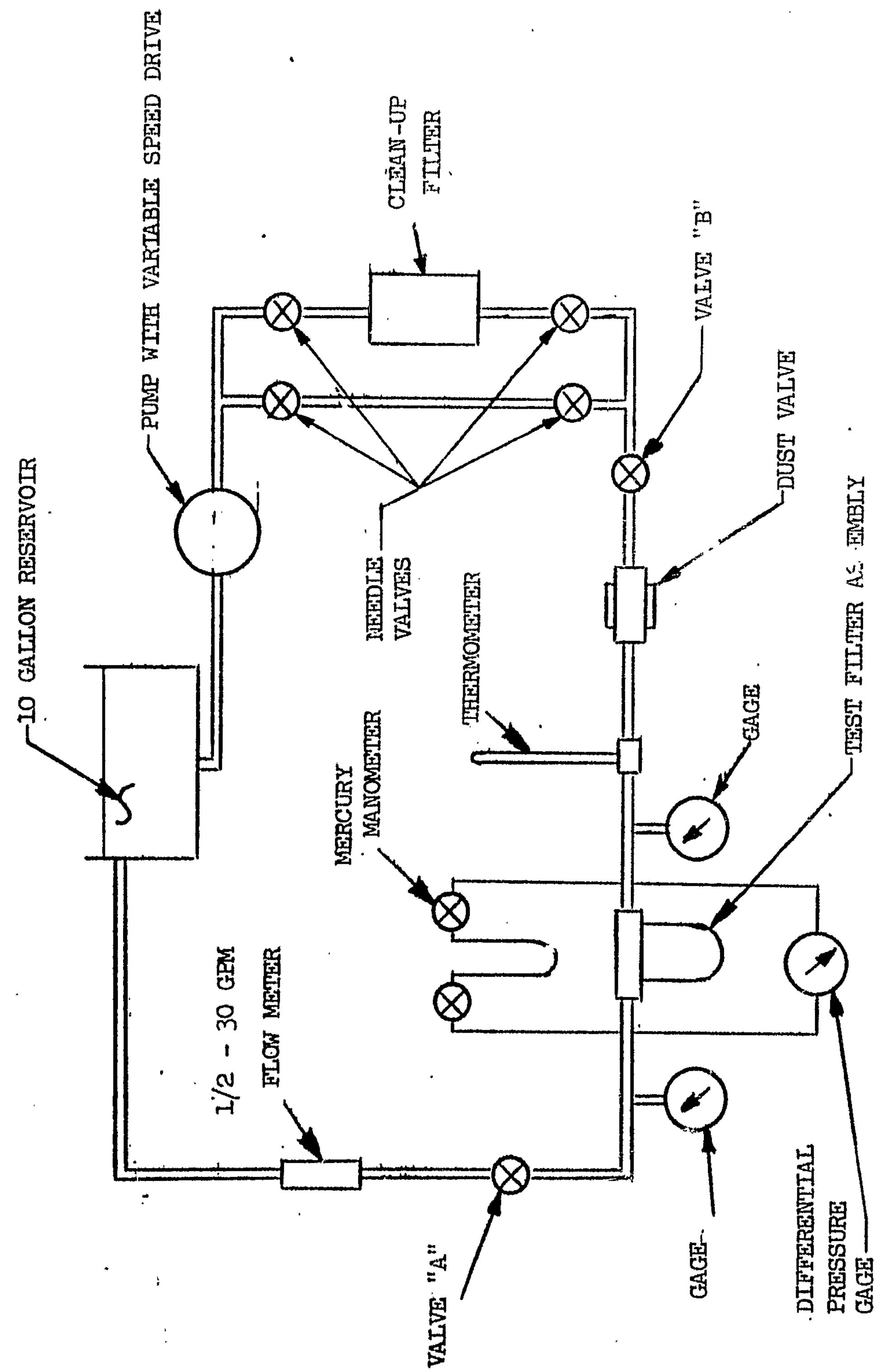


FIGURE 3

TYPICAL SET-UP FOR DETERMINING PRESSURE BUILD-UP AND COLLAPSE PRESSURE

FIGURE 4

EFFLUENT FILTRATION SET-UP

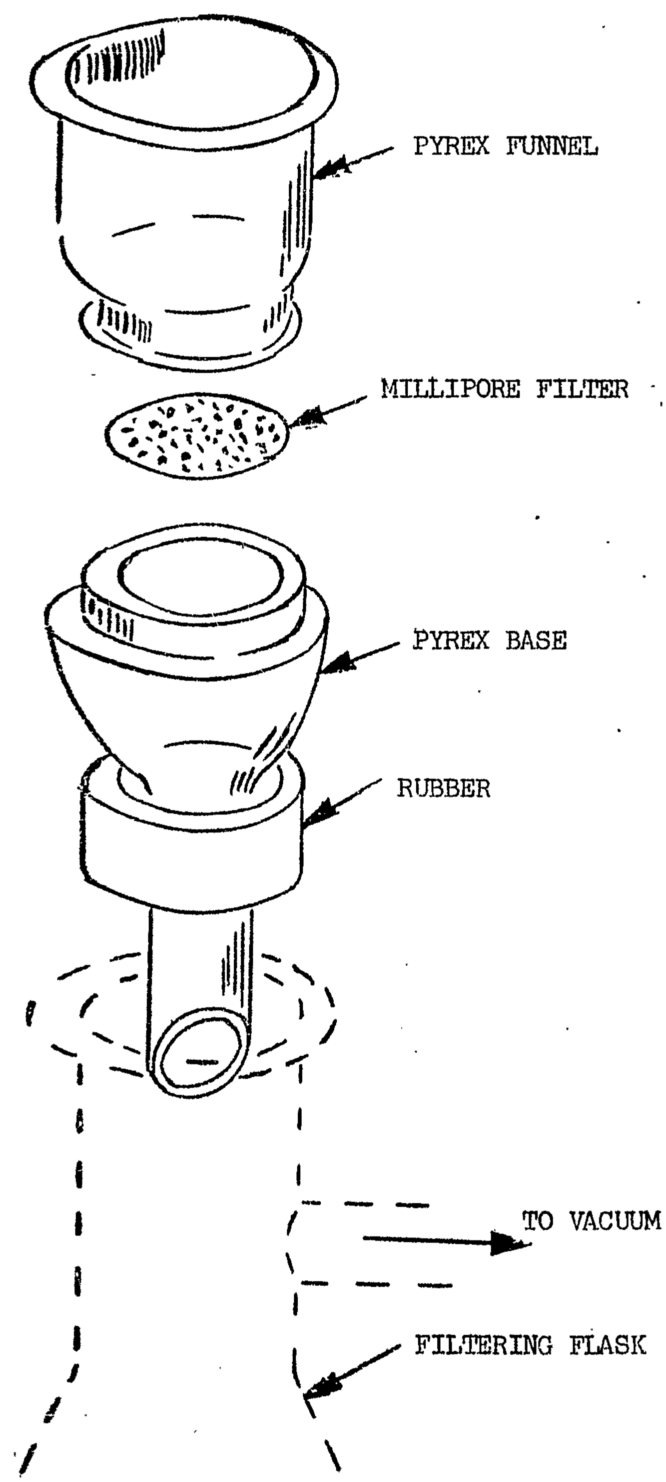
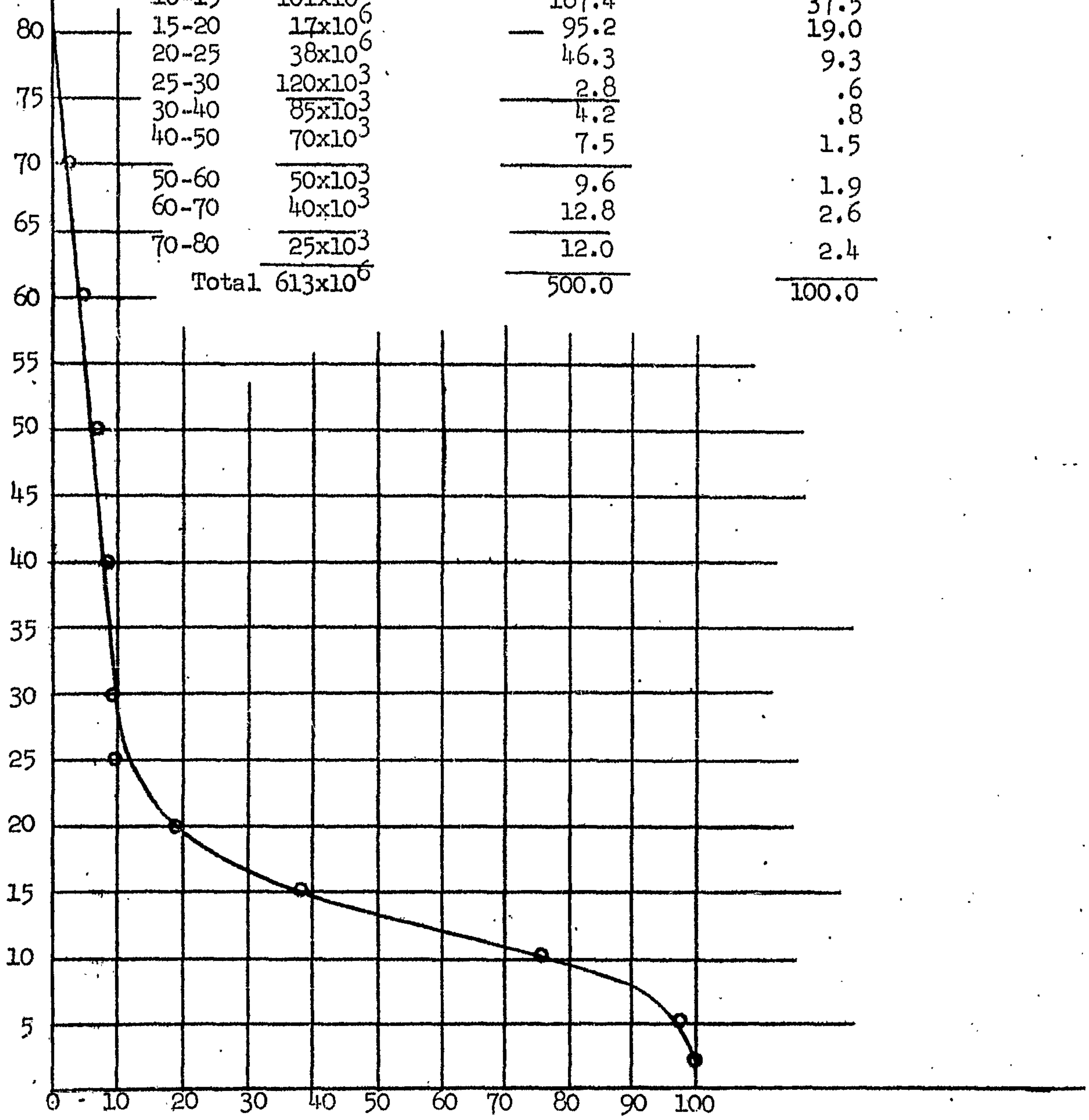


FIGURE 5

PARTICLE SIZE DISTRIBUTION CURVE
APMF-9 GLASS BEADS

SIZE RANGE MICRONS	NUMBER BY COUNT	WEIGHT MILLIGRAMS	% BY WEIGHT
0-2	$76x10^6$	0.2	.04
2-5	$190x10^6$	11.5	2.3
5-10	$225x10^6$	110.5	22.1
10-15	$101x10^6$	187.4	37.5
15-20	$17x10^6$	95.2	19.0
20-25	$38x10^6$	46.3	9.3
25-30	$120x10^3$	2.8	.6
30-40	$85x10^3$	4.2	.8
40-50	$70x10^3$	7.5	1.5
50-60	$50x10^3$	9.6	1.9
60-70	$40x10^3$	12.8	2.6
70-80	$25x10^3$	12.0	2.4
Total	$613x10^6$	500.0	100.0



CUMULATIVE WEIGHT FRACTION - PERCENT
Points on the line indicate portion of particles with sizes greater than diameter noted

FOR ERRATA

AD 273 210

THE FOLLOWING PAGES ARE CHANGES

TO BASIC DOCUMENT

Addendum to AD 273 210

MODULAR HYDRAULIC SYSTEM DEVELOPMENT
PROJECT HYDRATOY

ADDENDUM TO PART II
FINAL ENGINEERING REPORT
AER-E1R-13120
28 February 1962

Prepared Under Contract NOas 59-6019c
Bureau of Naval Weapons Equipment Division

Prepared by G. Gilder
Applied Systems Design

Approved by G. A. Starr
Chief, Applied Research
and Development

ADDENDUM TO SECTION IV, CONCLUSIONS

At the time the final report was prepared six valves were still undergoing qualification tests. The six units are as follows:

1. Relief valve - 25 GPM - Benbow Manufacturing Company
2. Two way, two position selector valve - 25 GPM - Hydro Aire Company
3. Three way, two position selector valve - 25 GPM - Hydro Aire Company
4. Solenoid operated sequence valve - 12 GPM - Hydro Aire Company
5. Four way, three position selector valve - 12 GPM - Ronson Hydraulic Units Corporation
6. Priority valve - 4 GPM - Fluid Regulators Corporation

Each of these units had been plagued with development problems which delayed the start of qualification. Several major design changes were made in each valve. This, of course, required that new hardware be fabricated each time a design change was found necessary. The problems encountered were typical of those discussed in Section III. The costs incurred by the manufacturers of these units rose appreciably because of the prolonged development period.

Only item 5, the face mounted four way valve, successfully completed qualification and is recommended for the qualified parts list.

Item 1, the pilot operated relief valve, failed in the endurance test by hanging in the open position. The cause of failure appeared to be dimensional instability of valve body and slider; therefore, a second valve was fabricated adhering to the heat treating practices discussed in Section III. This unit was subjected to the entire series of qualification tests

only to fail during the last portion of vibration test. Once again galling had occurred. The valve had an extremely flat flow versus pressure drop curve. While the unit holds much promise, further study of the materials used is needed to overcome its tendency to gall.

Items 2, 3, and 4 were being qualified simultaneously (in the same set up), but each experienced failures. Solenoid failures were the major problem with these units. Development of these three units has been terminated at the request of the manufacturer.

Item 6, the priority valve, entered qualification but subsequently began to function erratically. Rework and further development did not yield a valve which met requirements of the procurement specification. One sliding member within the valve has a very thin wall which is subjected to unbalanced pressures. The resulting distortion is sufficient to bind the slider and mating parts. Development has been cancelled at the request of the manufacturer.

Hardware produced has now been forwarded to the Hydraulics Laboratory at the U.S. Naval Air Material Center.

AD 273 210

END CHANGE PAGES